Analysis of Waste in the Production of Concrete Blocks - A Case Study in a Goiás Industry

Tatiana Gondim do Amaral
Teacher in Post-Graduation Program in Geothecnics
Structures and Civil Construction
Federal University of Goiás
Avenida Universitária, nº 1488
Setor Universitário
Goiânia - GO

Weslley M. Cruz

José R. Perim
Student of the Post-Graduation Program in Geothecnics
Structures and Civil Construction
Federal University of Goiás
Avenida Universitária, nº 1488
Setor Universitário
Goiânia - GO

Abstract

An ever more demanding consumer market and the need for companies to be more competitive have led organizations to try to eliminate waste. This research is a case study which presents a proposal for intervention in order to improve performance of a pre-cast concrete block factory in outer Goiânia. As a first step, waste in the production process was identified through analysis of data on time involved in each step of the process. Then, applying the concepts of Lean Production, a list of activities was drawn up with a view to eliminating non-value-added work, identifying waste, decreasing cycle time, streamlining the production process, and increasing the flexibility and transparency of the process. From the results it was possible to identify the sources of waste and provide management with information for strategic decisions about production. Finally, various suggestions were made with a view to eliminating or mitigating bottlenecks in the production process. These involved proposals for physical intervention with a new layout and management strategies as well.

Keywords: Lean Production, Waste, Concrete blocks, Continuous improvement

Introduction

From the late 1970s onwards, many industries underwent profound changes in the organization of their productive activities, which led to the establishment of new paradigms of production management. Many of these proposed changes in the new paradigm initially emerged in the Japanese automobile industry, and were broadly applied by Toyota Production System (Formoso, 2000, cited in Bernardes, 2001).

Koskela (1992) conceptualized and adapted this new paradigm of production management for the construction industry calling it Lean Construction. Lean Production is so called because it uses smaller amounts of everything when compared to mass production: half of the factory workers' labor, half of the investment in tooling, half of the time spent planning to develop new products in half the time. It also means fewer inventories at the factory, and results in lower rates of product defects and a larger, expanding variety of products (Womack et al., 1992, cited in Amaral, 2004). In addition to the basic concepts, Lean Production presents a set of principles for the management of processes, some of which are now presented: reduce the work which does not add value; enhance product value by considering consumer needs; reduce variability; reduce cycle time; simplify by reducing the number of steps and parts; increase output flexibility; increase process transparency; focus on control of the overall process; introduce ongoing improvement to the process; balance flow and conversion improvement; benchmark.

It is worth noting that if these principles for improving processes are to be deployed, requirements, such as commitment on the part of top management, a focus on measurable and viable improvements, employee involvement, and continuous formation are necessary.

According to Howell (1999), cited in Amaral (2004), the premises of Lean principles are basic, namely, to plan a production system to deliver a product instantly without maintaining any intermediate stocks. The concepts include identifying and giving the consumer value, eliminating everything which does not add value, organizing production as a continuous flow, posting information and delegating decision-making, pursuing perfection, delivering a product answering the requirements of consumers and leaving zero inventory.

For Heineck and Machado (1998), cited in Amaral (2004), it is possible to improve organizational objectives through Lean Production by keeping the various activities in constant motion, maintaining the various activities working (at the same rate) over time, avoiding peaks and valleys in production using consumer requirements to determine how activities are performed, anticipating the needs of production and consumers, foreseeing the needs of production and consumers since foresight is motivating for both, recognizing the unpredictability of processes, and maintaining ongoing negotiation between the needs dictated by production and the possibilities of implementing them, seeing to an increase in continuity of operations by reducing variability, coordinating the flow of resources and operations so that variations outside the scope of management during the process can be avoided, reducing waste in the processes, understanding waste as all that is not consistent with a balance between the aims and the means chosen in each circumstance.

The template is the same whether you are preparing a full length paper (10) or a short paper or industrial contribution (5-6 pages). The easiest way to ensure that your paper will conform to the required formatting is to save this file with a new name, and then write your paper directly into it, erasing the guideline contents as you go.

Waste

The logic of the Toyota Production System, advocated by Ohno, seeks to identify and eliminate all the waste which occurs during the value chain of the product/service. According to Ohno (1997), there must be a full understanding of the concept of waste, so that it can be detected and completely eliminated. According to him, it is necessary to divide the worker's involvement into two different dimensions: work and waste. Work can be subdivided into two groups: effective work – which adds value – and extra work which does not add value. Then the rate of work which adds value should be increased through eliminating waste, minimizing additional work and maximizing effective work.

As a basis for the systematic process of identifying and eliminating waste, Ohno (1997) and Shingo (1996) propose seven classes of waste:

Waste through overproduction - which can be further divided into quantitative and anticipated waste: quantitative overproduction is waste due to the production of more than the volume programmed while waste caused by anticipated overproduction is waste brought about by producing material before it is needed;

Waste due to transportation - all transport is waste and is ultimately optimized by total elimination;

Waste due to the processing itself – those processing activities which are not needed for the product/service to acquire the characteristics desired or specified by the consumer;

Waste due to manufacture of defective products – is the production of parts, subcomponents or finished products which do not meet the quality specifications required by the project;

Waste due to motion – the unnecessary movements made by operators while executing an operation;

Waste due to waiting – there are two types: waste due to a delay in the process, which arises, for example, when a whole consignment awaits dispatching while the previous one is still being processed, inspected or transported; and, waste caused by waiting for a consignment which happens, for example, when the components of a consignment wait until the processing of the entire consignment has been completed;

Waste due to inventory – the holding of inventory of raw materials, work-in-progress or finished goods.

Improvements

For Shingo (1996), the main improvements are necessarily associated with the process, because the processes serve the consumer and operations improve the efficiency of the parts. Thus, it is possible that even if operations produce excellent results, the production system as a whole is not optimized. Also according to Shingo (1996), fundamental improvements must be implemented, because they eliminate this phenomenon, and thus eliminate waste.

Shingo (1996) points out that improvement in the process is linked to how processing, inspection, transportation and waiting can be improved. Of these, only processing adds value; the others can be considered waste.

In addition, the elimination of waste can be brought about through improvements in the operational function: preparation - rapid change of tools; main operation - technological innovation and improvements in the clearances

- Automation, preventive maintenance and improvements in working methods, motivation and worker involvement.

Methodology

The Company in this case study is a medium-sized producer of pre-cast concrete blocks, located in the city of Goiânia. Concrete blocks for construction and interlocking concrete flooring are manufactured using vibro-pressing equipment, Piorotti Blocopac 900 and 750, respectively. Production is continuous, starting with the input of raw materials (cement, aggregates, water and pigment) at one end and ending with the product outlet at the other. A process flow chart is shown in Figure 1.

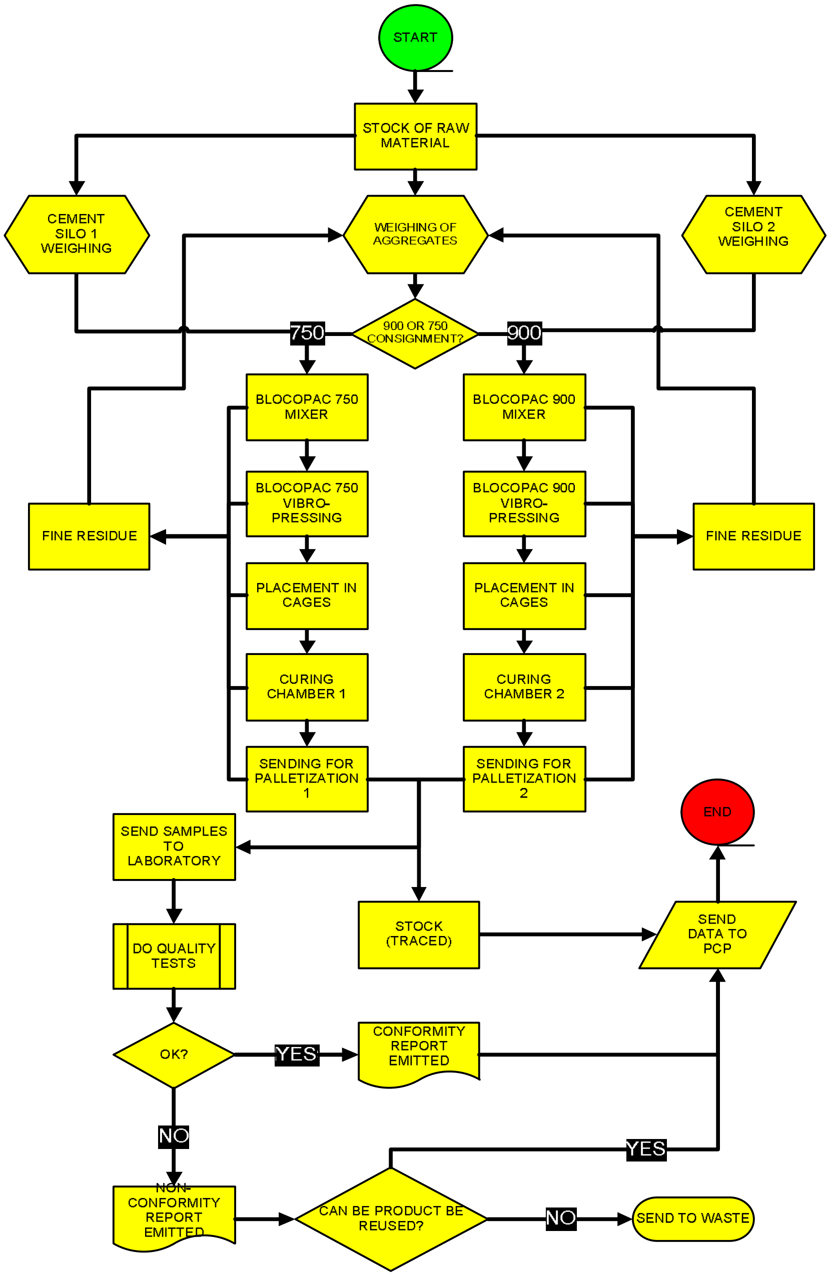


Figure 1: A Flow Chart of Manufacture of Blocks and Interlocking Concrete Flooring

The materials used in production are: natural sand, artificial sand, gravel (maximum diameter of 9.5 mm), coarse aggregate (maximum diameter 12.5 mm), CPII F-32 CIMPOR cement, water, pigments and additives. All coarse and fine aggregates are stored in bays, and the former are, in some cases, laid out in side bays for drying out purposes. Cement is stored in two metal silos, both of which are located next to the mixer of each vibro-press machine.

Figure 2 shows the aggregate storage bays and the measuring station.

Figure 2 - (a) Drying Bays ("Rest"), (b) Storage Bays, and (c) Measurement Stations

First, the aggregates are measured in a station equipped with a conveyor belt with a load cell. After weighing, the aggregates are transferred to the mixers by means of two conveyor belts, one inclined and the other horizontal. Cement, water and additives are added to the mixers. After mixing, the concrete is poured into the machine and vibro-pressed on metal plates. The final product is placed in wire cages and sent to the curing chamber. The following day the products are sent for palletizing and placed in storage. Figure 3 shows the stages of vibro-pressing, chamber drying and palletizing of blocks.

Figure 3 - (a) Exit of Blocks from Blocopac 900 (b) Drying Chamber, and, (c) Block Palletizing

A constant interruption in the production process, resulting in a failure to reach production targets, was the reason why the waste inherent in the process was analyzed. A survey was done of the time spent on the following stages of the production process in the Blocopac 900 machine: (a) weighing, (b) a conveyor handling 1, (c) mixing, (d) vibro-pressing, (e), conveyor handling 2, and, (f) placing in the wire cage. The average time for each stage and their respective standard deviations were recorded. This data was collected during the last week of October and first week of November 2010.

The object of the study was to identify bottlenecks in the process. Improvements which could be implemented in the overall process were analyzed, using a brainstorming technique with the engineer responsible for quality control and with the environment manager. Figure 4 shows the Piorotti factory layout.

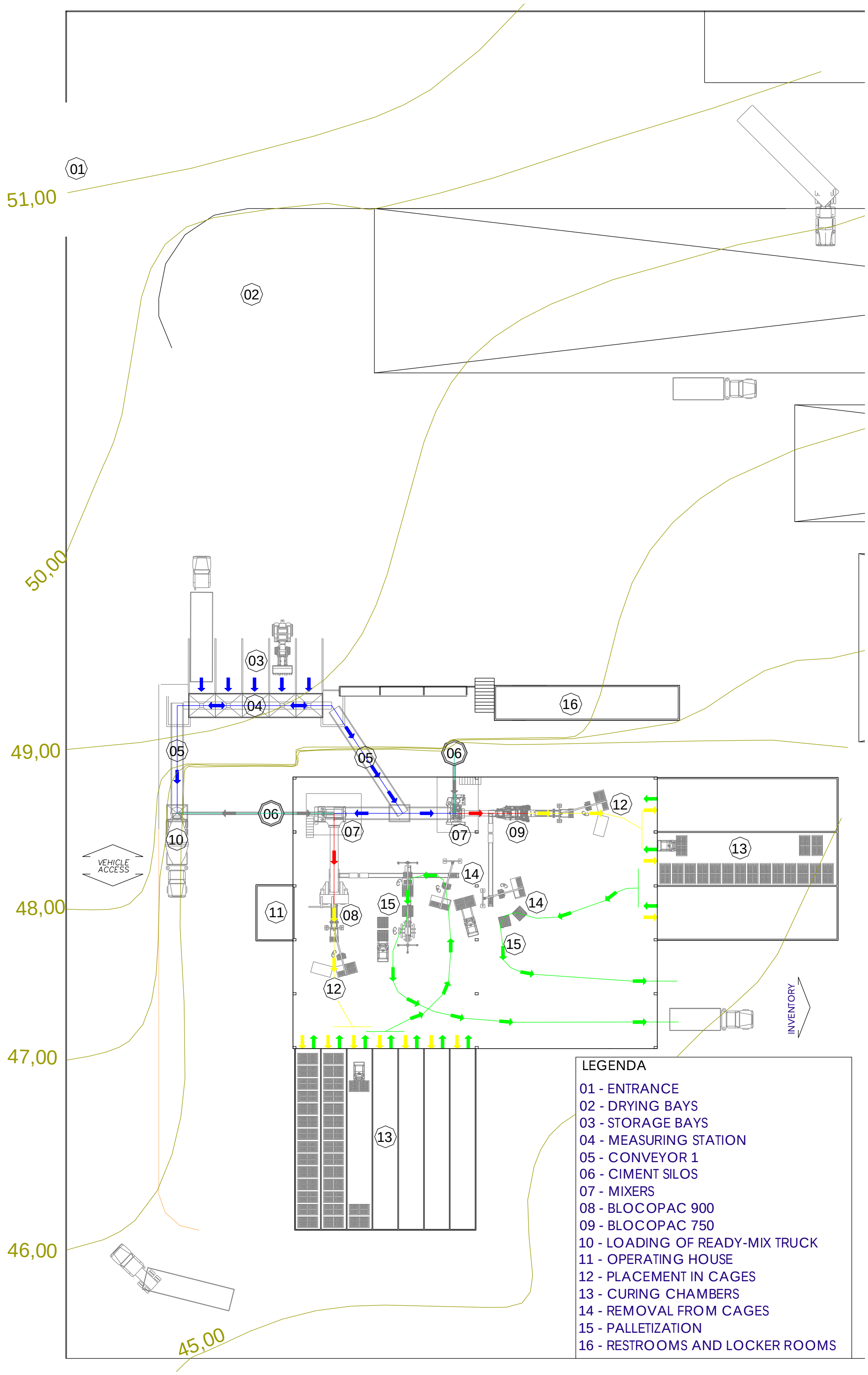


Figure 4 - Layout of the Piorotti Factory

Data was collected and measured by consignment, while times for vibro-pressing, conveyor belt handling 2 and placing in the wire cage were measured for one machine cycle.

This meant that the time spent on all the selected stages could not be evaluated. It was decided to adapt the time by multiplying the cycle time by the average of cycles per consignment on each of the days studied. However, these results must be corrected with new measurements.

Analysis of Results

Two graphs of the times found were made for analysis purposes, one, a bar chart, where the times of each consignment in each of the stages were compared, and the other, a pie chart, which showed the average amount of time spent on each stage. The standard deviation found in each stage was also calculated.

The data would indicate that there is a tendency towards a reduction in time spent going from the vibro-pressing stage to that of placement in the wire cages for each period analyzed (Figures 5, 6, 7 and 8). For the data presented in Figure 9, this is not clear for two consignments. This difference could be explained by the adaptation done to get the total time for placement in the cage, described in the previous paragraph.

This difference is more evident in the placement stage, as it is subject to time change due to the considerable variation in time that can occur while placing the plates in the cage. In these graphs, it can be seen that there is no upward or downward linear tendency, when comparing the times for the weighing, conveyor handling 1, and mixing stages for each day.

In Figures 5, 6, 7, 8 and 9 of the pie chart, it can be seen that data for the times for vibro-pressing took up the greatest part of the total stage of each day (between 23% and 31%), as well as giving rise to the largest standard deviations (ranging from 15 to 31%). Since vibro-pressing is an automatic stage requiring minimal human interference, it can be concluded there is poor adjustment or loss of work parameters. This deficiency could be explained by the erroneous introduction of parameters and/or loss of adjustment, throughout the day, due to a lack of preventive maintenance or training of employees.

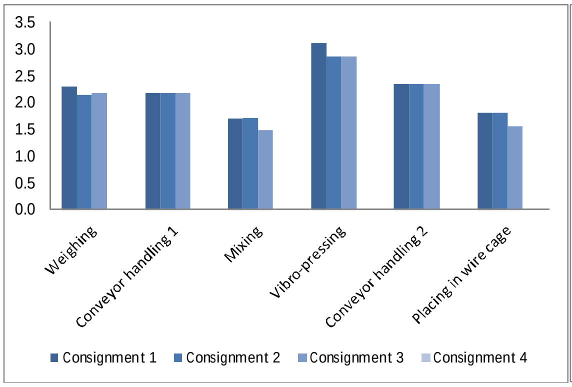
The data in Figure 5 show that the stages of weighing and conveyor handling1 occupy in all more than half the length of time spent on vibro-pressing. This shows the probability of a shortage of material for mixing if the station is concomitantly weighing consignments for the other machine (Blocopac 750). However, in the data for the other days (Figures 6, 7, 8 and 9) that did not happen. The quality control team noticed that when the aggregates in the bays are very wet, it is difficult for the material to fall from the station silos onto the weighing conveyor, and to fall from the conveyor handling 1 into the mixer. This highlights the need to expand, adapt the layout and adjust the rest bays, for drying the material arriving, and also the need to cover the bays to protect the aggregates from the rain.

As regards the mixing time, it can be seen from the bar and pie charts of Figures 5, 6, 7, 8 and 9, that there is a wide variation between the days (ranging from 0.8 to 3.6 minutes), and the tables show large standard deviations for the mixing stage. It was noted that the wide variation in the mixing times is due to the two sensors in the mixer. One of these measures the moisture of the material inside the mixer, which means that the quantity of water to be used in the mixture can be automatically calculated, based on the parameter of the total amount of water in the consignment. It was seen that waste mortar constantly accumulates on the sensor, to the extent that it affects the calculation of the amount of incoming water. The other sensor indicates whether the mixer contains material, allowing the hatch to close and begin weighing the components of the next consignment. However, when there is material covering this sensor, the system understands that there is still material in the mixer, so does not give the go-ahead to the sequence and thereby increases the mixing time. These interferences need to be corrected so that the streamlining of the work of the sensors is not thwarted.

Besides the above-mentioned interruptions in weighing, the weight of the ready-mix truck also substantially interferes with the process. This truck supplies concrete to that part of the company making pre-cast concrete structures. The loading of this truck should be transferred to another station so as not to interrupt the weighing process of the vibro-pressing machines.

Table - Sampletime of Blocopac 900 times

PRODUCT: 2.5MPa 14x19x39 cm Cavity blocks		Consignment	1159 kgs								
Nº 50PA271010	Cycles 1360		87 units								
Date: 27/10 2010	**Consignment 1**		**Consignment 2**		**Consignment 3**		**Consignment 4**		**Average time**		
Stages	**time (min)**		**time (min)**		**time (min)**		**time (min)**		**time (min)**		
	indiv.	**acum.**	**indiv.**	**acum.**	**indiv.**	**acum.**	**indiv.**	**acum.**	**indiv.**	**acum.**	**Deviation**
Weighing	2.3	2.3	2.1	2.1	2.2	2.2			2.2	2.2	0.09
Conveyor handling 1	2.2	4.5	2.2	4.3	2.2	4.4			2.2	4.4	0.00
Mixing	1.7	6.2	1.7	6.0	1.5	5.9			1.6	6.0	0.12
Vibro-pressing	3.1	9.3	2.9	8.9	2.9	8.7			3.0	9.0	0.15
Conveyor handling 2	2.3	11.7	2.3	11.2	2.3	11.1			2.3	11.3	0.00
Placing in wire cage	1.8	13.5	1.8	13.1	1.6	12.6			1.7	13.1	0.15
Total time (min)		**13.5**		**13.1**		**12.6**				**13.1**	



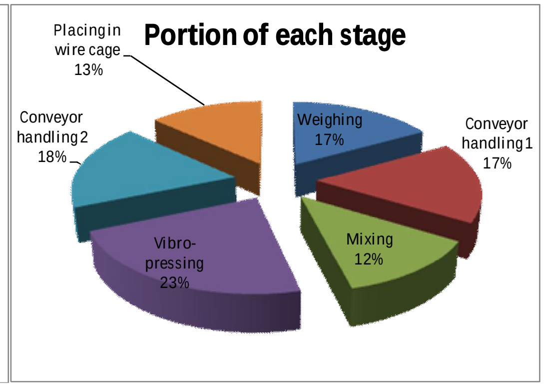
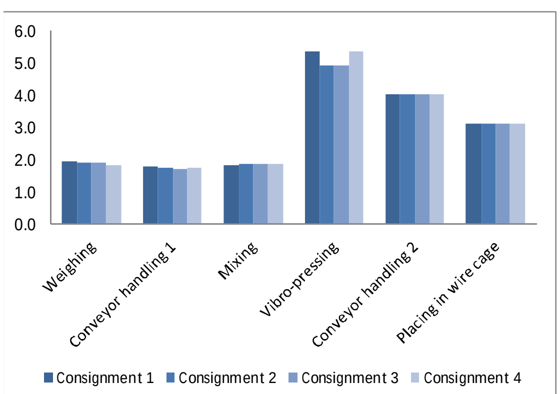


Figure 5 - Data for time spent making 2.5 MPa 14x19x39 cm cavity blocks: (a) table with times for each consignment and stage; (b) bar chart showing time for each consignment at each stage; and, (c) pie chart showing average times for each stage

Table - Sampletime of Blocopac 900 times

PRODUCT: 4.5MPa 14x19x29 cm Cavity blocks		Consignment	1620 kgs								
Nº 52PA281010	Cycles 1500		56 units								
Date: 28/10 2010	**Consignment 1**		**Consignment 2**		**Consignment 3**		**Consignment 4**		**Average time**		
Stages	**time (min)**		**time (min)**		**time (min)**		**time (min)**		**time (min)**		
	indiv.	**acum.**	**indiv.**	**acum.**	**indiv.**	**acum.**	**indiv.**	**acum.**	**indiv.**	**acum.**	**Deviation**
Weighing	2.0	2.0	1.9	1.9	1.9	1.9	1.8	1.8	1.9	1.9	0.05
Conveyor handling 1	1.8	3.7	1.8	3.7	1.7	3.7	1.8	3.6	1.8	3.7	0.03
Mixing	1.9	5.6	1.9	5.6	1.9	5.5	1.9	5.5	1.9	5.5	0.02
Vibro-pressing	5.4	10.9	4.9	10.5	4.9	10.4	5.4	10.8	5.1	10.7	0.26
Conveyor handling 2	4.0	15.0	4.0	14.5	4.0	14.5	4.0	14.8	4.0	14.7	0.00
Placing in wire cage	3.1	18.1	3.1	17.6	3.1	17.6	3.1	18.0	3.1	17.8	0.00
Total time (min)		**18.1**		**17.6**		**17.6**		**18.0**		**17.8**	



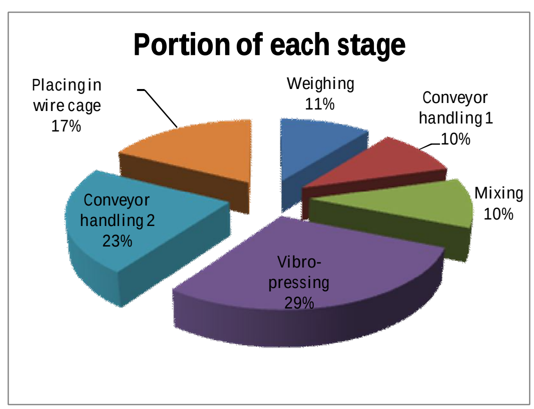


Figure 6 – Data for time spent making 4.5 MPa 14x19x29 cm cavity blocks: (a) table with times for each consignment and stage; (b) bar chart showing time for each consignment at each stage; and, (c) pie chart showing average times for each stage

Table - Sampletime of Blocopac 900 times

PRODUCT: 2,5MPa 9x19x39 cm Concrete blocks			Consignment	2290	kgs						
Nº 54PA291010	Cycles 1500			48	units						
Date: 29/10 2010	Consignment 1		Consignment 2		Consignment 3		Consignment 4		Average time		
Stages	time (min)		time (min)		time (min)		time (min)		time (min)		
	indiv.	acum.	indiv.	acum.	indiv.	acum.	indiv.	acum.	indiv.	acum.	Deviation
Weighing	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	0.01
Conveyor handling 1	2.4	4.3	2.4	4.3	2.4	4.3	2.4	4.3	2.4	4.3	0.01
Mixing	3.6	7.9	3.5	7.8	3.5	7.8	3.1	7.4	3.4	7.7	0.23
Vibro-pressing	6.3	14.1	6.3	14.1	6.3	14.0	5.7	13.1	6.1	13.8	0.26
Conveyor handling 2	4.7	18.8	4.7	18.7	4.7	18.7	4.7	17.8	4.7	18.5	0.00
Placing in wire cage	3.1	21.9	3.6	22.4	3.1	21.8	3.1	20.9	3.3	21.8	0.26
Total time (min)		**21.9**		**22.4**		**21.8**		**20.9**		**21.8**	

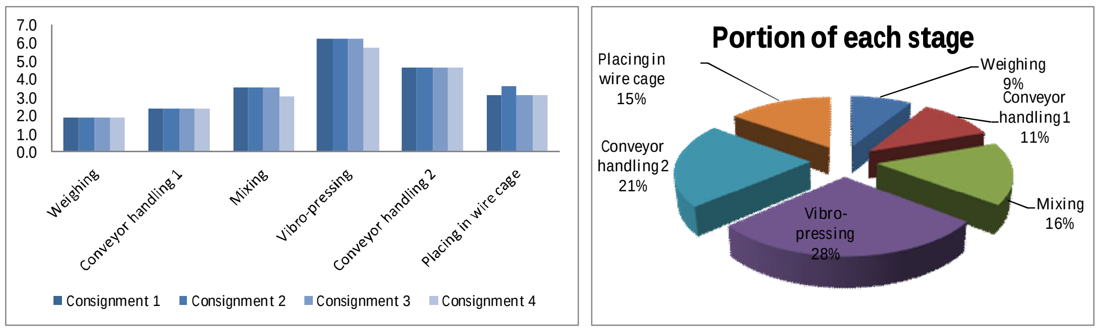


Figure 7 – Data for time spent making 2.5 MPa 9x19x39 cm concrete blocks: (a) table with times for each consignment and stage; (b) bar chart showing time for each consignment at each stage; and, (c) pie chart showing average times for each stage.

Table - Sampletime of Blocopac 900 times

PRODUCT: 8.0MPa 14x19x29 cm Structural concrete blocks			Consignment	2200	kgs						
Nº 04PA041110	Cycles 80			3	units						
Date: 04/11 2010	Consignment 1		Consignment 2		Consignment 3		Consignment 4		Average time		
Stages	time (min)		time (min)		time (min)		time (min)		time (min)		
	indiv.	acum.	indiv.	acum.	indiv.	acum.	indiv.	acum.	indiv.	acum.	Deviation
Weighing	1.0	1.0	1.0	1.0					1.0	1.0	0.02
Conveyor handling 1	2.4	3.4	2.3	3.3					2.4	3.4	0.08
Mixing	0.9	4.3	0.8	4.2					0.9	4.2	0.06
Vibro-pressing	5.3	9.7	4.9	9.0					5.1	9.3	0.31
Conveyor handling 2	4.0	13.7	4.0	13.0					4.0	13.3	0.00
Placing in wire cage	3.1	16.8	3.1	16.2					3.1	16.5	0.00
Total time (min)		**16.8**		**16.2**		**0.0**		**0.0**		**16.5**	

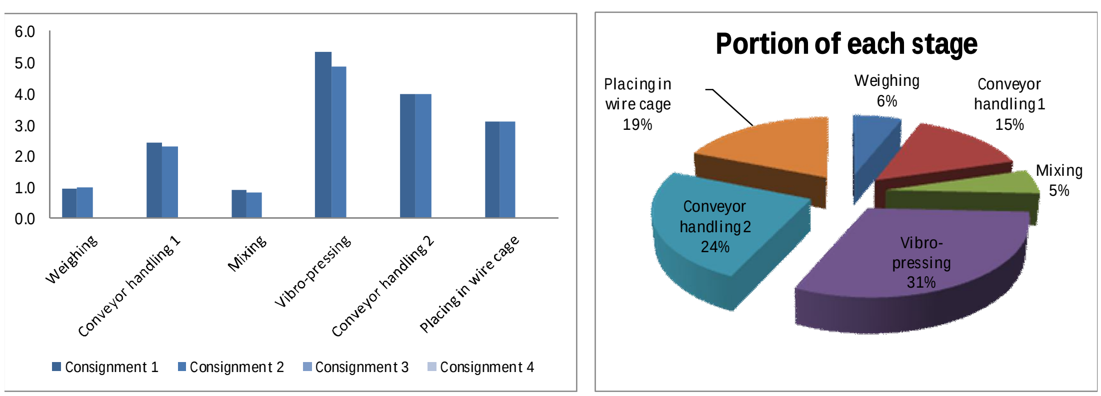
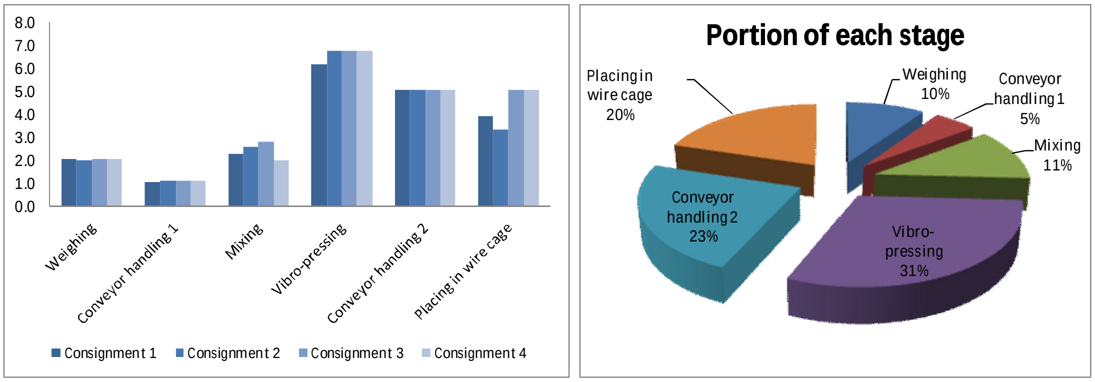


Figure 8 – Data for time spent making 8.0 MPa 14x19x29 cm structural concrete blocks: (a) table with times for each consignment and stage; (b) bar chart showing time for each consignment at each stage; and, (c) pie chart showing average times for each stage.

Table - Sampletime of Blocopac 900 times

PRODUCT: 2,5MPa 9x19x29 cm Concrete block											
Nº 06PA051110	Cycles 270		Consignment	2280 kgs							
				8 units							
Date: 05/11 2010	Consignment 1		Consignment 2		Consignment 3		Consignment 4		Average time		
Stages	tempo (min)		tempo (min)		tempo (min)		tempo (min)		tempo (min)		
	indiv.	acum.	indiv.	acum.	indiv.	acum.	indiv.	acum.	indiv.	acum.	Deviation
Weighing	2.1	2.1	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	0.02
Conveyor handling 1	1.1	3.2	1.1	3.2	1.1	3.2	1.1	3.2	1.1	3.2	0.02
Mixing	2.3	5.4	2.6	5.8	2.8	6.0	2.0	5.2	2.4	5.6	0.35
Vibro-pressing	6.2	11.6	6.8	12.5	6.8	12.7	6.8	11.9	6.6	12.2	0.28
Conveyor handling 2	5.1	16.7	5.1	17.6	5.1	17.8	5.1	17.0	5.1	17.3	0.00
Placing in wire cage	3.9	20.6	3.4	21.0	5.1	22.9	5.1	22.1	4.4	21.6	0.84
Total time (min)		**20.6**		**21.0**		**22.9**		**22.1**		**21.6**	



NB: The sensor was not releasing the mixture because it was covered with residue and gave the impression that mixer was still full and did not need to release the mixture. For this reason, there is a increase in time in some cases.

Figure 9 – Data for time spent making 2.5 MPa 9x19x29 cm concrete blocks: (a) table with times for each consignment and stage; (b) bar chart showing time for each consignment at each stage; and, (c) pie chart showing average times for each stage.

The graph in Figure 10 shows the variation of the standard deviations for each stage on the five days in which they were measured. It is evident that the conveyor handling 2 stage presented the lowest standard deviations and showed a continuous linear trend. The mixing stage presented deviation variations and the vibro-pressing stage presented the highest values of standard deviation. The placement in the cage stage showed marked variations, but this can be explained by the adjustments made as explained earlier.

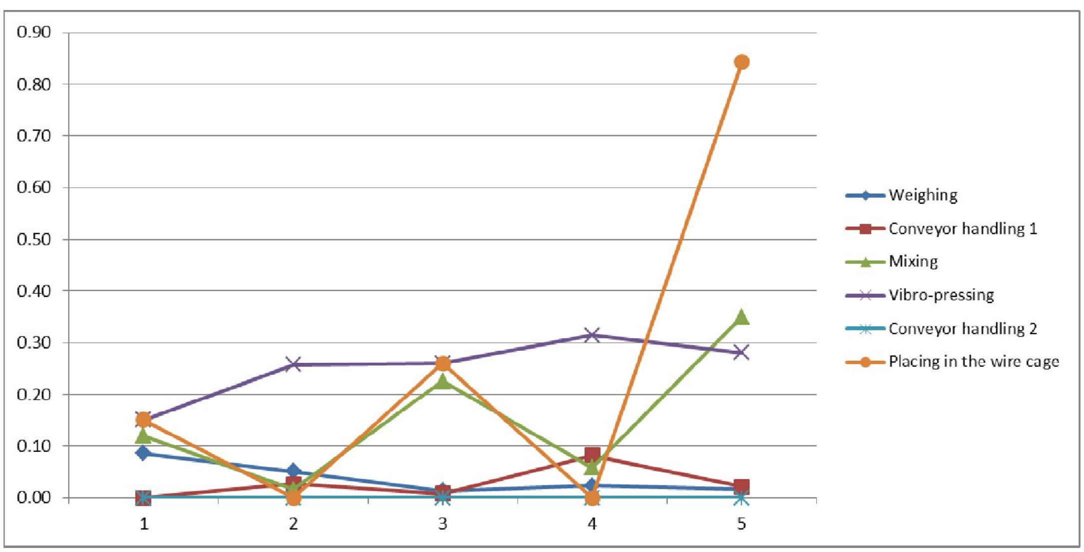


Figure 10 – Line Graph for the Standard Deviations of Mean Times in Each of the Stages Analyzed

From the analysis of this data a series of actions can be proposed to eliminate production bottlenecks:

Improve the layout (removal of concrete mixing shed and improved access ramp) in order to make the discharge of raw material (aggregates and cement) more efficient, as suggested in Figure 11;

Building of bays with a drainage system for drying out aggregates.

Roofing of rest and storage bays to reduce moisture in aggregates.

Trials to check aggregate quality parameters in order to adjust consignments using quality control.

Strict inspection and carrying out of preventive maintenance in machinery and equipment in order to avoid unwanted downtime and corrective maintenance.

Quality control as the product leaves the machine, prior to curing, in order to minimize the quantity of non-conforming products.

Set automation in order to reduce human intervention in the process of mixing and release of concrete, thereby solving the problem of the sensors.

Continuous training for all employees involved in the production process.

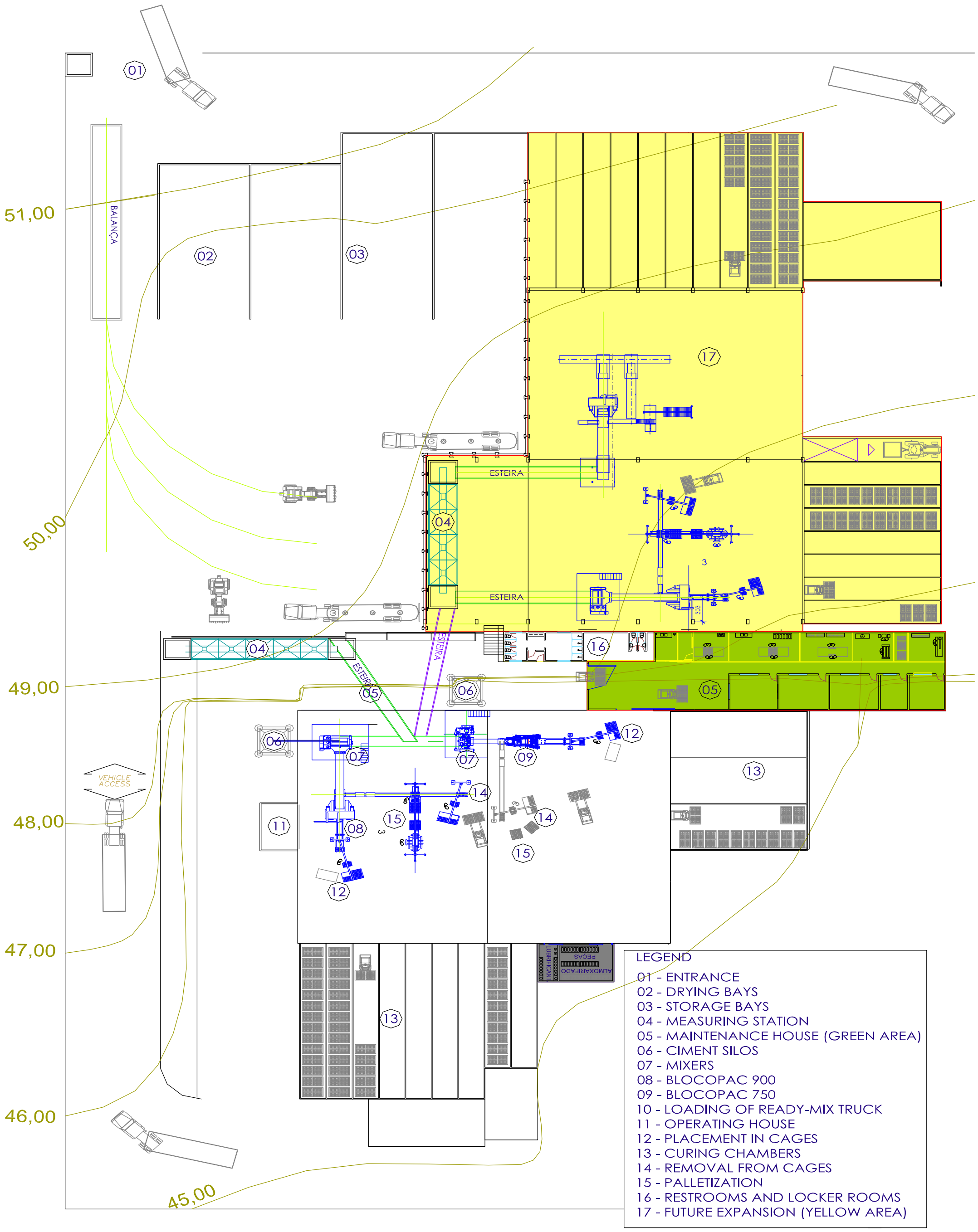


Figure 11 – Suggested Layout with Proposed Changes

Establishment of productivity goals, incentives for reaching the objectives established and reports with indicators for greater control of the whole process.

Increased transparency in the process, placing the information necessary for successful production (production schedule; product, consignment, period, etc.) at the disposal of all.

Improved transport flow in the moist curing chamber, where products will flow in a continuous, orderly and sequential manner.

Improved storage of deliverables so that loading for the end consumer is done optimally and sequentially.

Conclusion

Applying the principles of Lean Production leads to the identification of those parts which do not add value, recognition of waste in the productive process and suggestions for improvement. The main waste in the production process was analyzed and found to be caused by waste in inventory, transport and handling, waiting and in the processing itself. By implementing the suggestions made other benefits can be reaped, such as reduced cycle time, improved production flow balance and increased transparency in the process. The information obtained provides the management with subsidies for making decisions about production strategies.

However, efforts must be intensified and for better results there should be a focus on checking the overall process. Control of the production process should be used in a systemic way and ideals should be circulated among employees.

A suggestion for future studies would be to trace and cross reference data on variations in time spent making the product with their respective normative resistance results.

Acknowledgements

We would like to thank Goiás Artefatos Cimento Ltda. for their support and help in the smooth running of the research, Dr Tatiana Gondim do Amaral for her invaluable guidance, the PPG GECON (Graduate Program in Geotechnics, Structures and Construction material) at the Universidade Federal de Goiás, and CAPES for its financial support.

References

Bernardes, M. M. S. Desenvolvimento de um Modelo de Planejamento e Controle da Produção para Micro e Pequenas Empresas de Construção. 2001. 282p. Programa de Pós-Graduação em Engenharia Civil, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, 2001.

Womack, J. P., Jones, D.T. & Roos, T. A Máquina que Mudou o Mundo. Rio de Janeiro, Editora Campus, 1992. Koskela, L. Application of the New Production Philosophy to Construction. Technical Report Nr. 72, CIFE. Civil Eng. Dept., Stanford University, 75 pp, 1992.

Ohno, T. O Sistema Toyota de Produção: além da produção em larga escala. Porto Alegre: Editora Bookman, 1997.

Shingo, S. O Sistema Toyota de Produção: do ponto de vista da engenharia de produção. Porto Alegre: Editora Bookman, 1996.

Amaral, Tatiana Gondim do. Metodologia de qualificação para trabalhadores da construção civil com base nos conhecimentos gerenciais da construção enxuta. Florianópolis, 2004. 279p. Tese (Doutorado em Engenharia Civil). – Curso de Pós-Graduação em Engenharia Civil, Universidade Federal de Santa Catarina.

Amaral, Tatiana Gondim do.Proposta de intervenção em fábrica de pré-moldados utilizando os conceitos da construção enxuta. Revista Ciência & Engenharia, 2001.

Heineck, L. F. M., Costa, A. C. F., Santos, R. B. dos., Lima, F. B. de., Jungles, A. E.. Gestão dos fluxos físicos nos processos construtivos de canteiros de obras – edificações. IV SIBRAGEC, I ELAGEC, Porto Alegre, 2005.