# APPLICATION OF STANDARDIZED WORK IN FRANKI PILES CONCRETE WORK

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## ABSTRACT

The application of standardized work in manufacturing has resulted in many benefits, thus motivating researchers to apply it in the construction environment. The paper describes an application of standardized work in the task of Franki Piles concrete work. An exploratory case study was carried out in a residential construction project in Brazil. A method for standardized work application used in manufacturing and described in literature was taken as a basis and partially applied. The conclusions are that main steps of the method and as well as the procedures for data collecting, analysis and documentation of standardized work were successfully adapted to the construction environment studied. These were useful for characterizing wastes and discussing forms for eliminating it systematically, indicating potential gains in productivity of 45% for machines, and 70% for labour in an ideal implementation.

## KEYWORDS

Standardized work, Lean thinking, Construction.

## INTRODUCTION

Since the pioneering proposition by Womack and Jones (1996) regarding the five principles of lean thinking, the flow principle has been highlighted as a cornerstone of this philosophy. An element widely utilized to put in place this principle is standardized work (SW), which aims to keep the production as close to the continuous flow as possible (Liker, 2004). SW reduces wastes and the risk of accidents, and increases productivity and employee satisfaction (Kosaka et al., 2007).

In the construction context, the application of SW is still preliminary, rising the interest to be further studied. Some authors have discussed the importance of standardization in construction (Santos et al., 2002; Bulhoes et al., 2005; Nakagawa, 2005; Gallardo et al., 2006), but structured SW applications, considering several elements and support documents for analysis, as used in general in other industries, are not yet completely explored (Mariz et al., 2012).

Thus, the aim of this study is to analyse the applicability and potential usefulness of a structured SW method application in the construction environment.

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## STANDARDIZED WORK

Standardized work (SW) has its historical roots in the Training Within Industry Service (TWI) program, established in 1940 during World War II to increase production output to support the Allied Forces war effort (Huntzinger, 2005). Toyota made some minor additions and now utilizes the material to train thousands of workers (Liker and Meier, 2006). The TWI was structured in "J programs" were: job instruction, job methods, job relations and program development. The standardized work is a product of the program of job instruction, related to the way job is done and trained (Feng and Ballard, 2008).

SW means establishing precise procedures for each operator's work, based on three elements (Lean Enterprise Institute, 2003):

- **Takt time**: takt time is how frequently a product must be completed to meet customer expectations. It is calculated using customer demand and available time. Takt time sets the rhythm for standard work. (Rother and Harris, 2002);
- **Sequence**: sequence is the specific order an operator performs the manual steps of the process. The work sequence may be different from the process sequence. Focusing on the sequence identifies waste and stabilizes the process (Mondem, 1998);
- **Work-in-process** (WIP): work in process is the minimum amount of inventory on the line that will allow the operator to flow product efficiently (Ohno, 1997).

Several forms are used to support data collection and analysis in the SW application, usually referred to as SW documents. None of these documents deals with all the elements of SW, thus it is necessary their combined utilization to achieve meaningful results (Marksberry, et al., 2011). According to Lean Enterprise Institute (2003), three basic documents are commonly utilized in the creation of SW, they are:

- Production Capacity Form: this is used to calculate the capacity of each machine in a set of process to confirm true capacity and to identify and eliminate bottlenecks (Mondem, 1998);
- Standardized Work Combination Table: this table depicts the combination of manual work time, walk time, and machine processing time for each operator in a sequence (Lean Enterprise Institute, 2003);
- Standardized Work Chart: this shows operator movement and material location in relation to the machine and overall process layout (Liker and Meier, 2007).

Besides these three basic SW documents, other documents are usually used for SW application, such as Operator's Balance Chart, Machine´s Balance Chart and Process study sheet (Liker and Meier, 2006).

Rother and Harris (2002) discuss a continuous flow creation with a step by step analysis that results in a SW application. Their method is presented in 11 questions and two additional steps, summarized as follows:

1-Do you have the right end items?

2-What is the takt time?

3- What are the work elements necessary to make one piece?

4-What is the actual time required for each work element?

5-Can your equipment meet the takt time?

6-How much automation?

7-How can the physical process be laid out so one person can make one piece as efficiently as possible??

8-How many operators are needed to meet takt time?

9-How will you distribute the work among the operators?

10-How will you schedule the pacemaker?

11-How will the pacemaker react to changes in customer demand?

12-Implementing

13-Sustaining and improving

## RESEARCH METHOD

The research method adopted was an exploratory case study. Rother and Harris (2002) method was taken as a basis, following its steps for a structured analysis of the Franki piles concreting job. As this method was conceived for a manufacturing environment, the applicability and usefulness of each step and supporting documents was discussed, considering the peculiarities of the case. Questions 11 and 12, related to work programing, levelling and demand variation adaptability were not discussed in this exploratory study. Additional steps 12 and 13 related to implementation, maintenance and improvements also were not addressed, since the application was expected just in further projects of the company. The project is composed of 6 residential apartment buildings, 4 with 4 stores and 2 with 14 stores; the apartments have constructed area of 87 or 136 m2. The research was done during the foundation execution, in Franki piles[*]. The data collection on site was done during one week, focusing in the piles concreting work, using the referred method and respective data collection documents, including time measurement. Previous interviews with supervisors were used for a preliminary work sequence understanding, in order to orient data collection. After data collection, analysis and improvement proposals discussion was done by the researchers, following the main steps of Rother and Harris (2002) method. A potential productivity gain was estimated, considering an ideal implementation, since the proposals were not applied, since the piles construction phase was reaching the end.

[*] Franki piles are cast-in-situ concrete piles with an enlarged base obtained by powerful driving method http://www.geoforum.com/info/pileinfo/view.asp?ID=15 .

## RESULTS AND DISCUSSIONS

The questions proposed by Rother and Harris (2002) were applied to the case, resulting in the data and discussion presented as follows; questions focus are summarized.

- **Question 1:** Items selected

Rother and Harris (2002) use this question to analyze if the product family defined allows flexibility to include products with similar cycle times. In this case the only product studied was the Franki pile, not allowing an exploration of this analysis.

- **Question 2:** Takt time

Takt time is defined as the customer rate, obtained by the division of available working time by demand (Lean Enterprise Institute, 2003). The project schedule defined 4,1 months, with 21 working days of 8,8 hours each, for 509 piles execution, resulting in a takt time of 1h29min39s/pile.

This takt time can have its units translated for different processes. For example, each pile uses 14 concrete mixes and each mix demands one round trip of the compact loader, so the takt time of 1h29min39s/pile corresponds to 6min22s/mix for the mixer and 6min22s/trip for the compact loader.

- **Questions 3 and 4:** Necessary work elements and time for each one

In this steps the activities of dosing, mixture and transport were studied. Process Study Forms (PSF) were used to collect data, one for each operator: mixer operator, his assistant, and the compact loader operator. From PSF data an Operator Balance Chart (OBC) was drawn (Figure 1), were it is clear that the work lod is unbalanced among operators and all them have waiting time comparing to the takt time.

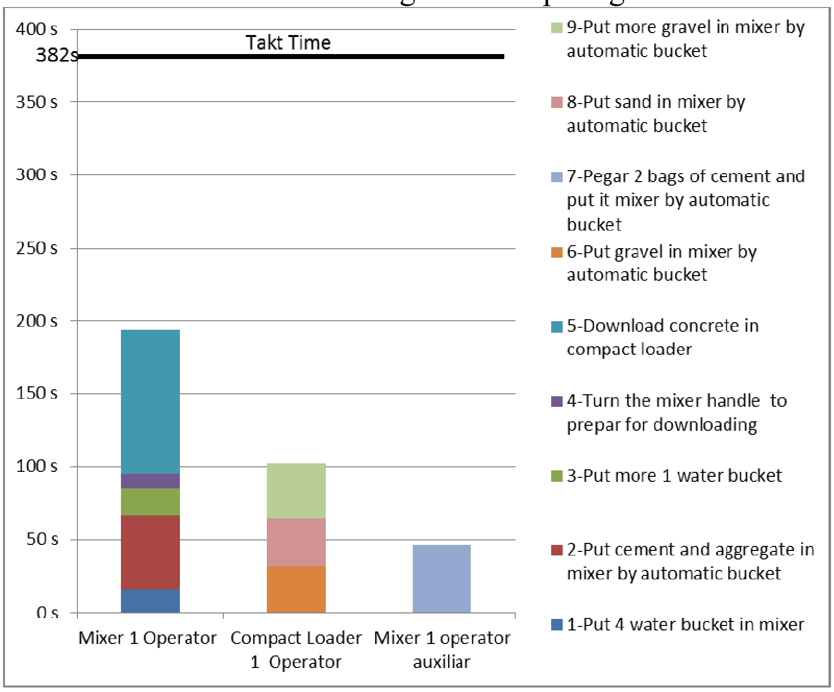


Figure 1: Operator Balance hart (OBC) – current state

**Question 5 and 6:** Equipment capacity comparing to takt time:

These questions are related to equipment, and have as main focus analyze if the machines have enough capacity, without bottlenecks, attending takt time. Question 6 is related to automation e.g. piece auto load and eject in manufacturing; in this case dosing was manual and mixer load was automated.

A Table of Production Capacity (TPC) was drawn (Table 1), showing the capacity per day for each equipment.

Table 1: Table of Production Capacity (TPC)

| **Table of Production Capacity** | | Proved for: | Work: Franki Pile / Application: Foundation | | | Takt time/day: 6 piles | | Registered for: |
|---|---|---|---|---|---|---|---|---|
| Nº | Process | Machine Name | Time (min) | | | Set up time | | Capacity per day |
| | | | Manual | Machine | Total | Piece /set up | Tempo [min] | |
| 1 | Concrete Mixing | Mixer | 45 | 42 | 87 | just end of the shift | 30 | **5,7 piles** |
| 2 | Concrete Transporting | Compact loader | 40 | 0 | 40 | just end of the shift | 30 | **12,6 piles** |
| 3 | Agregate Transporting | Compact loader | 23 | 0 | 23 | just end of the shift | 30 | **21,7 piles** |
| 4 | Pile driving and concreting | Pile driver | 100 | 0 | 100 | just end of the shift | 20 | **4,4 piles** |

For the takt time of 1h29m39s/pile and working hours of 8,8 hs/day, one gets 5,87 piles a day as necessary production; considering safety and practical issues, the necessary production was rounded up to 6 piles a day. The necessary number of mixers would be 1,05 (6/5,7); the managers could adopt kaizen activities to achieve necessary production with just one mixer, or adopt two, getting protection against any instability. Using the same rationale, one concluded that necessary equipment was: 1 compact loader for concrete and aggregates (for concrete 6/12,6=0,47 and for aggregates 6/21,7=0,27, total 0,74) , and 2 pile drivers (6/4,4=1,36).

The job site was using (current state) a total of 11 machines (3 mixers, 4 compact loaders (3 for concrete and 1 for aggregates), and 4 pile drivers). The machines were rented, so any reduction would represent immediate saving for the project. The numbers calculated using the TCP showed that 5 machines would be enough (2 mixers, 1 compact loader and 2 pile drivers).

- **Question 7:** Work station design and lay-out

This question focus the lay-out. In this case the job site logistics had been planned before, defining place for the mixers, material storage, transport routes, etc. Zones were defined for each pile drive, reducing the need movements. Thus the lay-out was considered already optimized and was not focus of proposed changes.

- **Question 8:** Number of workers needed

For the calculation of the number of workers needed it is necessary to divide the sum of work elements by planned cycle time. The cycle time adopted in general takes an allowance of a defined % bellow takt time, in order to prevent variations. In this case, it was considered cycle time=0,75takt time. Observing OBC – current state (Figure 1) and taking this cycle time, one can see that the mixer operator can get the work done by the assistant, not reaching the planned cycle time. So just considering work elements we conclude that just one mixer operator and one compact loader operator would be needed (see OBC future state - Figure 2). The OBC-future stat shows that the operators would have waiting time considering the planned cycle time, so other activities could be absorbed.

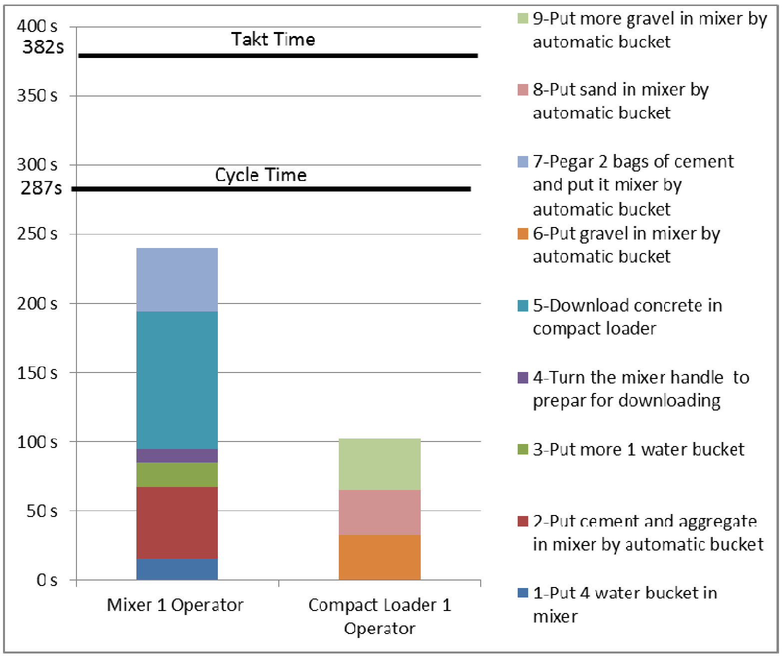


Figure 2: Operator Balance hart (OBC) – future state

- **Question 9:** Work distribution among operators

Question 5 discussion showed that 2 mixers could be adopted with reserve for variability, and question 8 showed that just one operator for the mixers is needed. This is possible, planning lay-out and standardized work to combine the worker moviments with automated time of the mixers. This is illustrated using the Standardized Work Combination Table (SWCT) (Figure 3) and the Standardized Work Chart (SWC) (Figure 4). The SWC includes quality and safety points of attention, showing the potential of SW to improve not just productivity but also other managerial aspects.

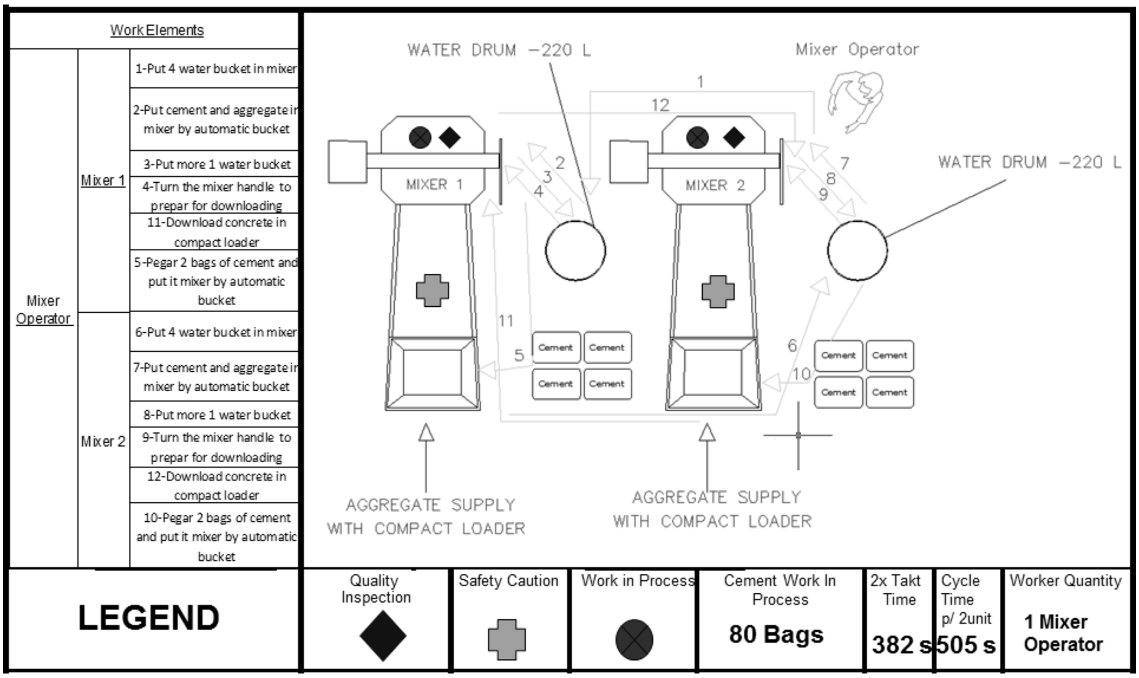


Figure 4: Standardized Work Chart (SWC) – Concrete mixing

While the current state uses 7 workers (3 mixer operators, 3 assistants and e 1 compact loader operator) the analysis showed that 2 workers could realize the work attending takt time (1 mixer operator and 1 compact loader operator), representing 71% productivity gain.

- Questions 10 and 11 and additional steps 12 and 13:

Questions 10 and 11 are related to the connection with customer demand and additional steps 12 and 13 with implementation, sustaining and improving, issues not addressed in this exploratory study.

| Standardized Work Combination Table | De: Put 4 water bucket in mixer | Date: 12/06/2011 | Unit per day: 84 | Manual (5s/ unit) |
|---|---|---|---|---|
| | Para: Pegar 2 bags of cement | Área: Job site | Takt-time: 382s | Machine (5s/ unit) |
| | | | Cycle time: 287s | Walk (5s/ unit) |

| Work Elements | | | Time (sec) Manual | Machine | Walk |
|---|---|---|---|---|---|
| Mixer Operator | Mixer 1 | 1-Put 4 water bucket in mixer | 16 s | | |
| | | 2-Put cement and aggregate in mixer by automatic bucket | 51 s | | |
| | | 3-Put more 1 water bucket | 18 s | 10 s | |
| | | 4-Turn the mixer handle to prepar for downloading | 10 s | 180 s | |
| | | 11-Download concrete in compact loader | 99 s | | 10 s |
| | | 5-Pegar 2 bags of cement and put it mixer by automatic bucket | 46 s | | |
| | Mixer 2 | 6-Put 4 water bucket in mixer | 16 s | | |
| | | 7-Put cement and aggregate in mixer by automatic bucket | 51 s | | |
| | | 8-Put more 1 water bucket | 18 s | 10 s | |
| | | 9-Turn the mixer handle to prepar for downloading | 10 s | 180 s | |
| | | 12-Download concrete in compact loader | 99 s | | 10 s |
| | | 10-Pegar 2 bags of cement and put it mixer by automatic bucket | 46 s | | |

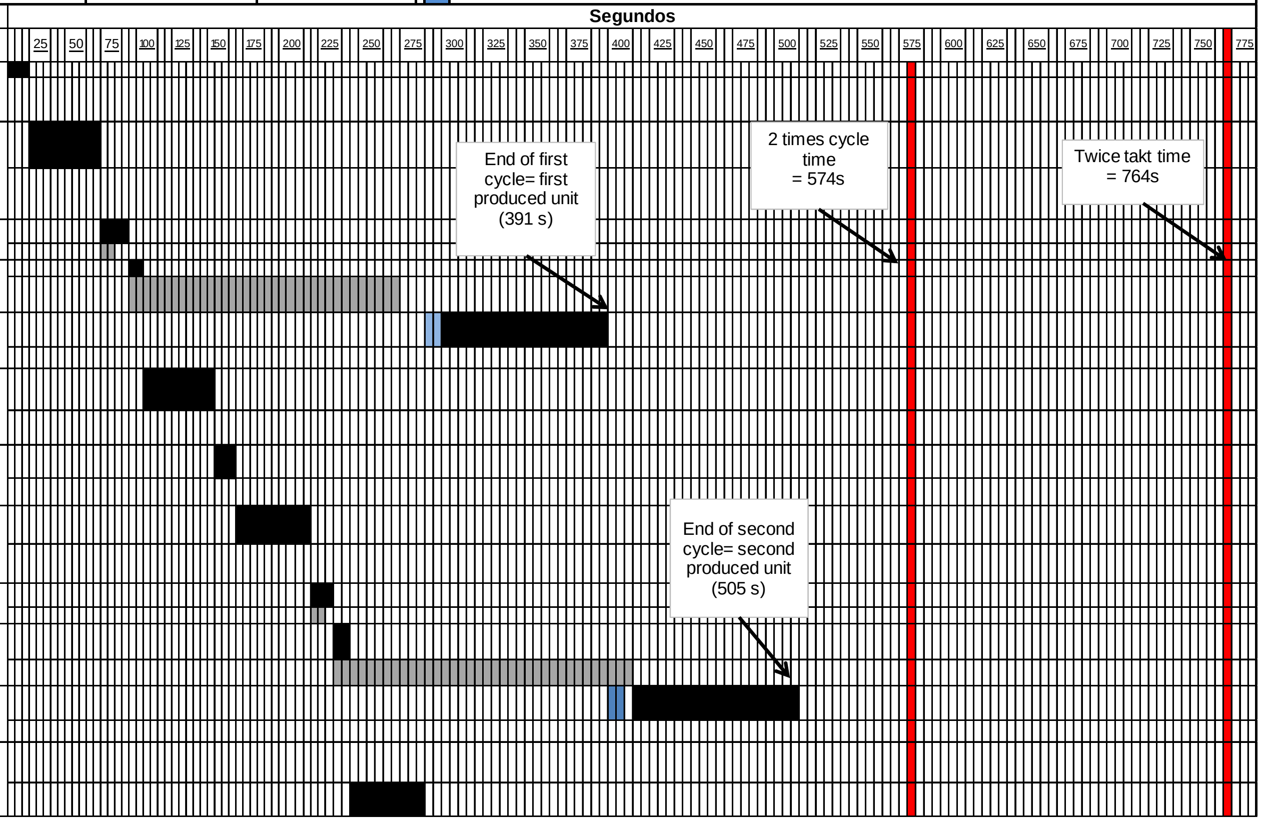


Figure 3: Standardized Work Combination Table (SWCT) – Mixer operator

## CONCLUSIONS

The use of their questions proposed by Rother and Harris (2002) provided a structured analysis that made possible a clear understanding of wastes in current state and the calculation of the necessary resources in future state, reducing waste. , that and made possible

Questions 1 to 6 provided an understanding of the current state. Drawing current state OBC and TPC and comparing resources with takt time highlighted the idleness of machines and workforce. Traditional planning process adopts historical data, which include all wastes from previous projects, and consider protections against unknown variability, resulting in over allocation of resources. Lean approach focus on identifying a process with minimum waste, being SW analysis one of its main tools for that.

Questions 7 to 9 conducted the analysis that resulted in a future state proposal represented by future OBC, SWCT and SWC, that would have potential benefits in productivity, quality, safety and process stability. In the case, this analysis showed potential reductions in machines (from 11 machines to 5) and 71% gain in workforce productivity. These gains depend on a disciplined implementation, sustaining and improvement, focused on steps 12 and 13, not explored in this study. Questions 10 and 11, also not explored, would provide necessary stability, dealing with connection to customer demand.

Although focusing just on the work design (questions 1 to 9), this case shows the usefulness of a structured analysis for the current state wastes understanding, in the process level. It also shows the usefulness of this analysis to design a future state, considering equipment and people detailed tasks. The questions and SW documents, taken from manufacturing practices, with minor format adaptations, showed no difficult to be applied in this construction case.

The potential gains are related to the way equipment and workforce could be planned using SW, affecting management decisions, and are not related to the specific work studied. This fact suggests a significant potential of application in other construction tasks, that should be explored in further studies, considering different situations, for example of different levels of people – equipment combination.

This was an exploratory case study, with limitations; the major one is that the improvements proposed using the method were not implemented. This is a suggestion for future studies, since the authors expect that this case and its potential results could motivate a more frequent use of standardized work analyses for the improvement of construction methods.

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