TECHNOLOGICAL INTERVENTIONS IN THE CONTROL OF SERVICES IN A LEAN ENVIRONMENT

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ABSTRACT

Lean construction concepts were used to improve concrete slab molding and mortar floor screeding operations. Detailed monitoring of site activities using handheld computers allowed the identification of cost reducing opportunities, both in relation to materials and labor. Floor screed was chosen as the first major building service to be improved, but soon concrete pouring followed suit according to the following steps: i) reduction of concrete slab height in the wet areas; ii) rendering of floor screed just after concrete pouring in an enlarged building cycle; iii) change from ready mix to on site concrete production; iv) increase in the number of formwork supporting props; v) leaving setting out marks on the floor screed to guide brickwork first course. Results are depicted using a comparative table showing general production indicators before and after processes were improved.

KEY WORDS

Technological intervention, floor screed for ceramic tiles, lean construction.

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INTRODUCTION

The lack of performance measurement is a problem that deeply affects the construction industry. This is to a great extent related to the attitude and lack of training of managers. Generally, they are used to making their decisions based on intuition and experience, rather than on objective measurement data. Moreover, devising a performance measurement system in the construction industry is a relatively difficult task for the following reasons: (a) construction is a project oriented industry: the product is usually unique in terms of design and site conditions, and a temporary organization needs to be created for each project; (b) construction projects tend to be relatively complex: there is a wide variety of materials and components involved, many different agents take part in the process, and the final product has a large number of performance attributes (Lantelme and Formoso 2000).

The application of lean principles takes into account characteristics of each different construction site, its management processes and objectives. Appropriate technological interventions might be introduced, while organizational lean thinking ideas are introduced. Cost accounting report on the technological intervention savings might be a first step in guaranteeing that lean interventions are financially worthwhile, recommending their further application.

Improvement in the construction sector is a topic of current debate. Construction companies and consultants are looking at ways of raising quality, lowering costs and shortening project times. This work is not going unnoticed by the clients of the sector who also see the potential benefits. Expectations have risen and new ways of working are being promoted to emphasize teamwork and greater involvement of the client organization (Leiringer 2000).

Information and communication flows have become more important to control, when attempting to reduce development times. Delivering the right information at the right place and throughout the entire process will help to eliminate a high number of non-value adding activities. These new demands need a more transparent housebuilding process, competent personnel (education and training), and an ability to perform changes necessary to survive in a competitive market (Lindfors 2000).

This research work aims at showing the changes that took place in the process of execution of a service through a number of technological interventions. They took place in a managerial environment were it was necessary first to give strong evidence of money saving possibilities of lean principles.

THE PROCESS OF EXECUTION OF THE FLOOR SCREED FOR CERAMIC TILES BEFORE TECHNOLOGICAL INTERVENTIONS

DETERMINATION OF THE THICKNESS OF THE FLOOR SCREED

A 23 (twenty three) story high tower block was being constructed under managerial control of the authors. Technological innovation initiatives started while the reinforced concrete structure was under construction. At the time, it was considered that this activity was already sufficiently streamlined by the use of proper metallic formwork, ready mix concrete delivery and laser controlled leveling. But it was noted that concrete slabs did not have a set back to accommodate extra thickness of impervious material that will cover wet areas (balconies, kitchens and bathrooms). For the determination of the thickness of the floor screed for the whole pavement it is first necessary to set the thickness of the complete floor screed in the wet areas, including impervious material and floor tiles. Based on that thickness the rest of floor screeding will be laid, adding an extra centimeter. This extra space would accommodate the common practice found in this region of the country that leaves the finished level of pavements a little higher that the finished level of wet areas. Spill over will not occur when cleaning the wet areas with plenty of water. The thickness of wet areas floors is determined by a number of layers as follows:

- Floor screed for leveling off concrete slab: 10mm
- Waterproofing material: 5mm
- Floor screed for ceramic tiles: 25mm
- Set back between the finished level of the whole pavement and finished level of wet areas 10mm
- TOTAL: 50mm

The thickness of the floor screed is therefore a minimum of 50mm. Figure 1 shows diagrammatically the thickness of wet areas on top of the concrete slab.

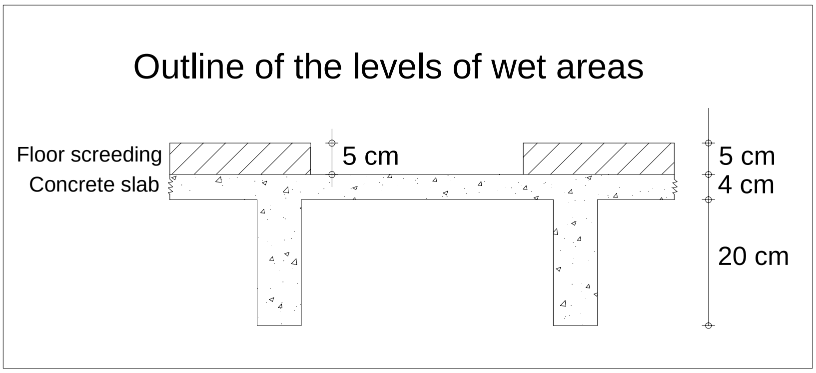

Figure 1: Outline of the floor thickness for wet areas

THE OLD BUILDING PROCESS FOR FLOOR SCREEDS

Observations aiming at developing a new technology for this operation started on the second floor of a total of 23 that make part of the main tower block. All flow and conversion activities were described in terms of their details and cost were collected. Table 01 shows all labor and material for the process, starting with discharge of cement from lorries up to final execution.

The activities for the execution of floor screeding for ceramic tiles begin with the receiving and visual inspection of materials. Laborers will take care of cement discharge from lorries, taking it to the concrete mixer. Two laborers and a concrete mixer operator are responsible for producing the floor screed mortar. Mortar is then transported to the ongoing pavement. A laborer in charge of all transportation within a pavement is responsible to take the wheelbarrow full of mortar from the lift and hand it to the floor screed execution gang. A bricklayer and a laborer form the execution team in each pavement.

The execution process begins with the determination of the floor screed level using a laser level. Mortar is then thrown directly in the concrete slab that should be previously wet. The bricklayer distributes mortar along the horizontal slab using an aluminum ruler to get the right thickness and finishing.

SUMMARY OF COSTS

After defining all the flow and conversion activities, measurement data was collected for each. Table 1 exhibits costs of the floor screed for the second story of this building. Discharge of cement and sand, mortar transportation and handling of cement bags at the mixing unit might be taken as flow activities. Floor screeding execution is a conversion activity.

Table 1: Total Cost - Floor screed second story

Activities		Dates							TOTAL
		16/oct	17/oct	18/oct	19/oct	23/oct	24/oct	25/oct	
Cement bags		15	15	17	16	16	14	5	98
Production (m²)		38,65	37,13	41,26	40,25	24,11	42,66	19,76	243,82
Discharge Cement (R$)		0,27	0,27	0,31	0,29	0,29	0,25	0,09	1,77
Discharge Sand (R$)		0,11	0,11	0,12	0,11	0,11	0,10	0,04	0,70
Mortar (R$)	Servant	3,50	3,50	3,97	3,73	3,73	3,27	1,17	22,87
	Professional	2,27	2,27	2,58	2,43	2,43	2,12	0,76	14,86
Transport (R$)	Servant	5,00	5,00	5,66	5,33	5,33	4,66	1,67	32,65
	Professional	4,25	4,25	4,82	4,54	4,54	3,97	1,42	27,79
Execution (R$)	Servant	7,33	7,33	7,33	7,33	7,33	7,33	3,67	47,65
	Bricklayer	12,46	12,46	12,46	12,46	12,46	12,46	6,23	80,99
Total Labor (R$)		**35,19**	**35,19**	**37,25**	**36,22**	**36,22**	**34,17**	**15,03**	**229,27**
Labor taxes (R$)		32,94	32,94	34,87	33,91	33,91	31,99	14,07	214,63
Material (R$)	Sand	34,02	34,02	38,56	36,29	36,29	31,72	11,34	222,24
	Cement	177,00	177,00	200,60	188,80	188,80	165,20	59,00	1156,40
Total Material (R$)		**211,02**	**211,02**	**239,16**	**225,08**	**255,08**	**196,95**	**70,34**	**1408,65**
Total Value (R$)		***279,16***	***279,16***	***311,28***	***295,22***	***295,22***	***263,11***	***99,44***	***1822,59***

Figure 2 shows the final aspect of floor screeding. At the uppermost part of the picture it is possible to see the 5cm setback for wet areas (a balcony in this case).

Figure 2: Floor screed executed with 50mm thickness

A NEW PROCESS OF FLOOR SCREEDING EXECUTION

Engineers, foreman, bricklayers and laborers got together to find new ways to execute floor screeding. Among several ideas some were successfully implemented like the ones described below. It will be noticed that operations remained almost the same, in terms of the micro-activities they encompass. That is, checking, loading, transporting, waiting remained the same for the new operations: in fact, technologically speaking only the quantity of materials that were moved decreased substantially. Moreover, organizationally only two different gangs of operatives were put to work together. It might be observed in table 2, that labor input remained almost the same, while major savings were connected to the smaller use of building materials. Reducing the non-value adding part of the job and increasing work synchronization were the inspiring lean production concepts behind the innovations described in the next paragraphs.

USE OF SETBACKS OF 2CM MOLDED WHILE POURING THE CONCRETE SLAB OF WET AREAS

The structural engineer responsible for the design of the reinforced concrete structure allowed the reduction of total slab thickness in the wet areas. The floor screed of the whole non-wet area decreased to three centimeters. Just with this design decision a considerable reduction in floor screeding mortar concrete usage was expected. Clearly this innovation was based on reducing the number or quantity of non-value activities, like extra mortar to increase the height of concrete slabs in non-wet areas. Figure 3 shows a cross section for the new floor screeding.

The first trial was not successful due to the use of ready mix concrete on site. Concrete delivery and placement were performed in a hurry, making it difficult to ascertain correct slab thickness and the precise marking of the wet areas.

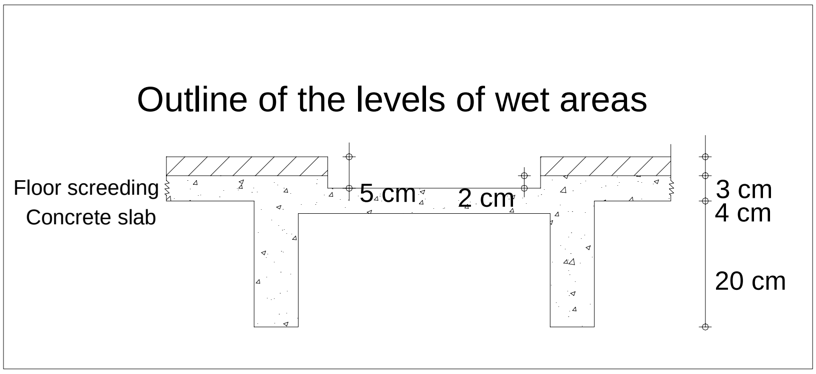

Figure 3: Outline of the levels of the wet areas

ON SITE CONCRETE MIXING INSTEAD OF READY MIX SUPPLY

After the verification that the idea had not generated the expected result, the discussion turned to a different solution to the problem. The ready mix concrete supplier could not guarantee synchronous concrete deliveries to the site. Not only was a timetable not respected but also the intervals between truck arrivals were at random, so that it was no surprise when two trucks would get to the site at the same time.

Ready mix concrete was pumped with a working life of two hours, before it starts to harden. The quality of the concrete finishing was affected by hurry. Apart from that the vibration of the concrete delivery ductwork affected the small beams of the slab grid, putting them out of position.

The development team concluded that it was necessary to mix concrete on site, in order to have a synchronous production, transportation, delivery, pouring and leveling cycle. Apart from operational advantages, the cost of producing concrete on site is less than buying it ready mix, provided the builder could guarantee its quality.

CONCOMITANT EXECUTION OF FLOOR SCREED AND CONCRETE SLAB

The mixing of concrete on site gave rise to another idea. It was decided to mould the floor screed just after concrete slab pouring and leveling. The floor screed is placed on top of fresh concrete. Both final level of the concrete slab and final level of the floor screed are checked to keep the latter with 3 (three) centimeters. It is quite usual according to Brazilian concrete slab molding practice that this part of the concrete structure will not have a leveled finishing, making the floor screed responsible for that, with varying thickness along the pavement. Thus reduction of thickness variability was accomplished while bringing together two activities. Both reduction of variability and a cellular like arrangement of work are modern managerial principles associated with lean thinking. Figure 4 shows a general view of this new method.

Figure 4: Molding of slab with concrete mixed on site

Moreover, setting out marks were left on the still fresh finished floor screed surface, making it easy to further lay the first bricklaying course. Thus an extra activity was incorporated, avoiding the need for a more complicated transferal of building design measures to the actual working area, at the start of the succeeding brickwork activities. As the pace of work was governed by on site concrete production, plenty of time was available to perform this extra activity, without making floor screeding rhythm slower than concrete pouring. Synchronization and balancing the rhythm of work were lean production principles behind this technological innovation.

INCREASE IN THE NUMBER OF PROPS TO SUPPORT FORMWORK FOR BOTH CONCRETE SLAB AND FLOOR SCREED

The number of metallic props supporting the slab formwork was designed taking into account only fresh concrete weight. With the concomitant execution of floor screed it was necessary to increase the number of supporting props. Moreover, concrete cure and the removal of props were done with greater care, since no slab deformation could be tolerated. Normally concrete slabs will sag, with floor screeds being used afterwards to level the surface again in order to receive the ceramic tiles. Thus sacrifices were made in relation to the installation and removal of props. The objective was to improve the balanced flow of work of two other more costly operations. Care with the optimization of the whole building process, rather than an optimal solution to individual activities is the lean principle behind this increase in costs for propping.

RESULTS OF THE TECHNOLOGICAL INTERVENTIONS

As a result of those interventions cost were reduced as depicted in Table 2.

Table 2: Total Cost - Floor screed seventeenth story

Activities		Dates					TOTAL
		11/mar	12/mar	13/mar	14/mar	15/mar	
Cement bags		2	20	8	12	9	51
Production (m²)		7,75	91,76	37,70	62,10	62,50	261,81
Discharge Cement (R$)		0,04	0,36	0,14	0,22	0,16	0,92
Discharge Sand (R$)		0,01	0,14	0,06	0,08	0,06	0,36
Mortar (R$)	Servant	0,47	4,67	1,87	2,8	2,1	11,90
	Professional	0,30	3,03	1,21	1,82	1,36	7,73
Transport (R$)	Servant	0,67	6,66	2,66	4,00	3,00	16,98
	Professional	0,57	5,68	2,27	3,41	2,56	14,48
Execution (R$)	Servant	7,33	7,33	7,33	7,33	7,33	36,65
	Bricklayer	24,92	24,92	24,92	24,92	24,92	124,61
Total Labor (R$)		**34,31**	**52,79**	**40,47**	**44,57**	**41,49**	**213,63**
Labor taxes (R$)		32,12	49,42	37,89	41,73	38,85	200,00
Material (R$)	Sand	4,54	45,36	18,14	27,22	20,41	115,67
	Cement	23,60	236,00	94,40	141,60	106,20	601,20
Total Material (R$)		**28,14**	**281,36**	**112,54**	**168,82**	**126,61**	**717,47**
Total Value (R$)		***94,56***	***383,57***	***190,90***	***255,12***	***206,95***	***1.131,10***

Reductions of floor screeding total cost from the second to the seventeenth story can be observed. All the technological interventions allowed the notable reduction of 38% in terms of costs. Figure 5 shows the decrease of cement consumption in the execution of the floor screed. There was also reduction in the time of execution of the service. The most abrupt change is observed in the thirteenth story, when finally all technological developments were sufficiently mastered and both concrete slab pouring and floor screed were taken as one single operation.

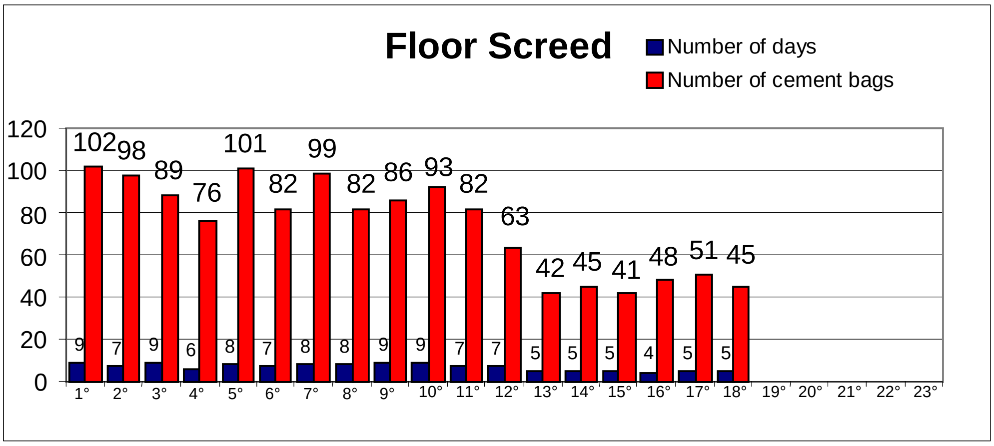

Figure 5: Accompaniment of consumption of cement bags and duration of execution of the floor screed

It should be taken into account that those savings are only connected to the floor screeding operation. Mixing, transporting and spreading concrete prepared on site cost more R$ 600,00 per story, a number that almost completely offset those floor screeding savings. But concrete production on site represented a further economy of R$ 2.400,00 per story, due mainly to savings in raw material costs, when compared with ready mix commercial prices. So there is a net saving of R$ 1.800,00 for the concrete operation plus R$ 691,49 for floor screeding. Total savings are in the region of R$ 2.491,49, what represents 12% of the total combined cost for both operations.

CONCLUSIONS

With all the technological interventions, it was possible to change the processes in accordance with lean concepts. Rhythm, work synchronization, labor involvement, avoidance of non-value activities and design features, slow but effective pace of work, and information gathering were all put together, allowing some 38% reduction in the cost of floor screeding and 12% reduction on the combined cost of this operation and concrete structure. At the time this paper was produced, other building operations were started, like roof rendering and bricklaying. The use of lean principles will inspire other technological innovations for these activities that will be reported in the near future.

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