WHY IS ON-SITE FABRICATION OF CUT & BENT REBAR PREFERRED IN TURKEY?

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ABSTRACT

Off-site fabrication of materials is a key feature of lean construction. However, the tradition of the industry has long been to fabricate materials on-site, and there are various factors that compel contractors to continue that tradition. These factors are especially powerful in developing countries. As an example, there is a strong preference for fabricating cut & bent rebar on-site in the Turkish construction industry. Using open-ended interviews, this study identifies the reasons for that preference and offers recommendations for improving off-site fabrication performance in Turkish construction. This study suggests that the preference for on-site fabrication of cut & bent rebar is based on the lack of management capability of contractors including the poor coordination capability and the defective ordering procedure, and it enables contractors to fiddle the numbers on workers and scrap in order to increase the money they receive from clients. The paper hopes to make a contribution to the theory and practice of lean implementation, especially in developing countries.

KEY WORDS

Developing countries, Implementation, Cut & bent rebar, On-site fabrication, Off-site fabrication.

INTRODUCTION

The chronic problems of construction are well-known: low productivity, poor safety, inferior working conditions, and insufficient quality (Koskela 1997). Similar problems are also encountered in manufacturing. However, those problems have been overcome by implementing lean production theory. Since the construction industry differs from other industries in many ways, it is commonly argued that the implementation of lean production in construction would not be as successful as it was in manufacturing. The peculiarities of the construction projects are as follows: 1) one-of-a-kind nature of construction projects, 2) site production, 3) temporary multiorganization, and 4) design-bid-build system (Koskela 1997). On the other hand, these peculiarities can be overcome by means of implementation of the lean production theory in construction, which is defined as lean construction (Melles 1997). Lean construction techniques roughly include; 1) one-of-a-kind features are reduced through improvement of standardization, modular components, and off-site fabrication, 2) difficulties of site production are improved through increased prefabrication, temporal decoupling and through specialized or multi-functional teams, 3) the number of temporary linkages between organizations is reduced through encouragement of longer term strategic alliances, and 4) the problems resulting from the sequential procedure of design-bid-build system are overcome by concurrent engineering (Koskela 1997, Crowley 1998).

Great performance improvements have been achieved through implementation of lean construction techniques in the construction industry. The study of Kartam (1995) revealed that implementation of lean construction techniques reduced project duration by 20% to 55% and improved productivity by 10% to 37%.

One of the lean construction ideals is to simplify site installation to final assembly and com-

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missioning. Moving toward that ideal allows application to construction of modular design, advanced manufacturing capabilities, and supply chain management. The job of construction management expands beyond the site to coordinating on-site and off-site activities. These are fundamental changes that promise a radically different way of delivering and managing construction projects, with massive reductions in time and cost (Gibb 1999). On the other hand, there are various factors that compel contractors to fabricate construction materials on-site. Those factors are especially powerful in developing countries.

This study aims to identify the main reasons behind the preference in Turkish construction for on-site fabrication of cut & bent rebar. Although there are numerous materials used in the construction process, this study focuses on the supply chain of a single material, namely cut & bent rebar used in the construction of reinforced concrete structures. Cut & bent rebar was selected for study because 1) the main activities related to cut & bent rebar can be considered as a manufacturing process-cut & bent rebar is delivered from one workstation to another throughout the supply chain, and 2) cut & bent rebar can be fabricated either on-site or off-site.

The paper has the following sections: a brief background is provided, the collection and analysis of data is described, on-site and off-site fabrication processes are mapped, drawing on the earlier study of Polat and Ballard (2003), then the main reasons for preferring on-site fabrication are identified and a set of recommendations for improvement of off-site fabrication performance in Turkish construction are proposed.

BRIEF BACKGROUND: ON-SITE AND OFF-SITE FABRICATION PRACTICES OF TURKISH CUT & BENT REBAR SUPPLY CHAINS

Polat and Ballard (2003) investigated the prevalent cut & bent rebar supply chain configurations in the Turkish construction industry and they found that five different kinds of cut & bent rebar supply chain configurations are commonly used. Although five different kinds of configurations are exercised, those configurations can basically be categorized into two main groups, which are; 1) on-site fabrication, and 2) off-site fabrication.

In the supply chain configuration of cut & bent rebar, which represents the most commonly used on-site fabrication practice; the engineering firm is in charge of all activities involving designing, detailing and reckoning. The fabrication of cut & bent rebar is performed by laborers on site workbenches. Since most Turkish contractors do not have in-house capability to execute the designing, detailing and reckoning activities, this configuration is the most common. In this configuration, interdependence between the participants is less than in the other configurations. All of the data necessary for the contractor to initiate procurement and fabrication is generated by the engineering firm. A disadvantage of this configuration is that the contractor receives the documents after all of the designing, detailing and reckoning activities are accomplished. This sequential (cascading) configuration does not allow the participants to solve problems at the right time, and thus leads to rework (Polat and Ballard 2003).

The supply chain of cut & bent rebar, which represents the most commonly used off-site fabrication practice, is similiar to the configuration mentioned above. However, there are some differences. While in the on-site fabrication practice, fabrication is performed by the contractor, in the off-site fabrication practice, it is performed by the rebar fabricator. If the contractor does not have sufficient in-house capacity to fabricate the cut & bent rebar, the fabricator is charged with fabrication. Reciprocal dependence between the rebar fabricator and the contractor in this practice is high. If the contractor does not provide accurate and timely information to the fabricator, the delivery of cut & bent rebar to the site is delayed, and installation begins late (Polat and Ballard 2003).

Although lean construction advocates off-site fabrication of construction materials, both the study of Polat and Ballard (2003) and the interviews with practitioners revealed that on-site fabrication is most commonly preferred in the Turkish construction industry rather than the off-site fabrication of the cut & bent rebar.

Definitely, the foremost reason behind that preference is that most Turkish contractors believe that the cost of on-site fabrication of rebar is lower than off-site fabrication. A study by Polat & Ballard (2005) seems to confirm that kind of consideration of the Turkish contractors as it suggests that on-site fabrication of rebar results in less cost to the contractor. However, it should be kept in mind that the economic analysis presented in that study is based on a number of assumptions regarding managerial capabilities and ethical practices, which may be more or less representative of the Turkish construction industry as a whole. This paper is devoted to better understanding those assumptions and the obstacles to the lean transformation of the Turkish construction industry in order to establish the initial framework for the 'infrastructural' changes that should be accomplished in the Turkish construction industry before its participants can enjoy the benefits of lean construction.

RESEARCH METHODOLOGY

Main participants in the supply chain for cut & bent rebar in Turkey are: 1) Engineering firms, 2) Rolling mills, 3) Rebar fabricators, 4) Contractors (Polat and Ballard 2003). Designers (architect, electrical engineer, mechanical engineer etc.) and steel mills (manufacturing steel billets) may play a role in this supply chain; however, they are not central to the action, so they are not considered in this study.

In order to identify the main reasons behind the Turkish construction preference for on-site fabrication, several firms involved in the rebar supply chain were visited and practitioners were interviewed from 2 engineering firms, 7 contractors, 3 rolling mills, and 2 rebar fabricators.

Since this study aims to identify the main reasons behind the Turkish construction preference for on-site fabrication, the thoughts of each rebar supply chain participant about this subject were very important for the validation of this research. Therefore, several firms involved in the rebar supply chain were visited and the practitioners from 2 engineering firms, 7 contractors, 3 rolling mills, and 2 rebar fabricators were interviewed. Since it was the first study questioning the main reasons for the on-site fabrication preference in the Turkish construction industry, interviews were the appropriate means for conducting such a research.

The interviews consisted of open-ended questions, which roughly include:

1. Which type of cut & bent rebar fabrication practice, namely on-site or off-site, is most commonly preferred in the Turkish construction industry?
2. What are the main reasons behind that preference?
3. What is the current state of the off-site fabrication practices of cut & bent rebar in the Turkish construction industry?

3.1. What are the main advantages of off-site fabrication?

3.2. What are the main problems encountered by the rebar fabricators?

While all of the questions were asked to the each practitioner from the rebar supply chain participant company, question 3 was only asked to the rebar fabricator. As it was previously stated by Polat and Ballard (2003), all of the respondents reported that on-site fabrication is most commonly preferred in the Turkish construction industry rather than off-site fabrication. Based on the answers of the interviewees, the main reasons behind that preference and the current state of off-site fabrication practices of cut & bent rebar in the Turkish construction industry are summarized in the following sections.

CURRENT STATE OF THE OFF-SITE FABRICATION PRACTICES OF CUT & BENT REBAR IN THE TURKISH CONSTRUCTION INDUSTRY

The interviews with practitioners revealed that while there are numerous rolling mills that manufacture straight rebar, there are a small number of rebar fabricators in Turkey that cut and bend rebar to specific project requirements. There is no official data regarding the exact number of rebar fabricators managing their business in Turkey. The interviews with rolling mills, rebar fabricators and contractors revealed that although there are more than one hundred rebar fabricators in Turkey, there are only three rebar fabricators, two in Istanbul and one in Ankara, that manufacture cut & bent rebar with high quality by means of computer integrated machines. The interviews with rolling mills, contractors and rebar fabricators revealed that other fabricators are unqualified and use manual cutting and bending machines rather than computer integrated machines. The interviewed contractors reported that when they work with that kind of unqualified rebar fabricators, they experience various problems including low product quality, long lead times, and unreliable deliveries.

The interviewed rolling mills and contractors recorded that there are two rebar fabricators in Istanbul, which are competent and use computer integrated machines. Both of those rebar fabricators were visited, and the presidents and the production managers of these rebar fabricators were interviewed in order to identify the main advantages of off-site fabrication and basic problems encountered by the rebar fabricators.

The interviews with those rebar fabricators revealed that only 1-2% of total rebar used in Istanbul and Ankara is fabricated off-site. The remainder are cut and bent on site. Off-site fabrication of cut & bent rebar costs a contractor 10-12% more than purchasing straight bar. The price for off-site cutting and bending includes the fabricator's cost of labor and scrap (material waste). However, if a contractor is purchasing large quantities of cut & bent rebar, the rebar fabricators commonly fix the fee for labor and scrap throughout the project.

MAIN ADVANTAGES OF OFF-SITE FABRICATION

The rebar fabricators reported that off-site fabrication provides contractors with several benefits, which include:

1. *Removes investment tied up in cutting & bending machines*. Contractors utilize manual cutting and bending machines for on-site fabrication of rebar. Both of those machines cost more than $10,000 and they normally have a working life of more than 10 years. Figure 1 depicts a rebar bending machine and Figure 2 depicts a rebar cutting machine.

Figure 1: A manual rebar bending machine

2. *Removes wages for workers in charge of cutting and bending rebar*: The daily wage of a worker in charge of cutting and bending rebar is approximately $25 including all taxes. For instance, four[3] workers are required for cutting and bending rebar, two for the cutting machine and two for the bending machine. These workers move rebar from storage to the cutting machine, install rebar onto the cutting machine, cut rebar, move the cut rebar to the bending machine, install cut rebar onto the bending machine, and bend cut rebar. This means that $100 is spent per day for workers employed throughout the construction of the superstructure.

Figure 2: A manual rebar cutting machine

3. *Removes rebar waste encountered during the on-site fabrication process*: Sources in the literature (Bossink and Brouwers 1996, Formoso et al. 2002) claim that approximately 16-26% (by weight) of the total purchased amount of rebar is wasted during the construction process. Figure 3 shows an example of material waste resulting from cutting uneconomical shapes.

Figure 3: An example of material waste resulting from cutting uneconomical shapes

4. *Removes costs associated with keeping inventory:* Since the off-site fabrication process is highly predictable and is subject to less uncertainty contrary to on-site fabrication, on-site fabrication practices require large safety stocks to keep production going in case something negative happens. Keeping large safety stocks increases storage cost, financing cost and handling cost (Alhabashi 1991). Furthermore, off-site fabrication removes the cost of double handling in the case of achieving JIT delivery. Figure 4 shows piles (inventories) of straight rebar, and Figure 5 shows piles of cut & bent rebar, both on site.
5. *Reduces cycle time*: Since the rebar fabricators utilize computer integrated machines (see Fig-

3 The number of workers required for cutting and bending rebar was derived from the seven trade center projects in Istanbul investigated previously. The contract values for those projects varied between $3,000,000 to $35,000,000).

Figure 4: Piles of straight rebar

ure 6) to fabricate cut & bent rebar whose capacities are much more than the cutting and bending machines utilized during on-site fabrication, the productivity of off-site fabrication is much more than the productivity of on-site. Therefore, the time required for fabrication is reduced. Further, since off-site fabrication can be done concurrently with the installation of previously delivered materials, project durations are reduced.

Figure 5: Piles of cut & bent rebar

MAIN PROBLEMS ENCOUNTERED BY THE REBAR FABRICATORS

The rebar fabricators reported that they experience severe problems resulting from the following issues:

1. *Low quality of the purchased raw material*: Commonly, rebar fabricators use coil rod and contractors use straight rebar as a raw material. While the cutting and bending machines used for on-site fabrication are not appropriate for coil rod, the computer integrated machines used for off-site fabrication is appropriate for coil rod. The unit price of coil rod is much cheaper than straight rebar. Furthermore, when coil rod is used the waste amount due to cutting uneconomical shapes is less than the practice in which straight rebar is used. The rebar fabricators stated that their price for cut & bent rebar is cheap if it is considered that their price includes material waste (scrap) and labor. The main reason is that they use coil rod rather than straight rebar. The rebar fabricators claimed that the frequency of defect encountered in the coil rod is much more than it is in the straight rebar. They also stated that coil rod becomes twisted during the fabrication process. Thus, the rebar fabricators have to make some adjustments in terms of changing the angle (since the coil rod distorts from plane) or length (since the coil rod yields more than it was stated in the specifications) in order to meet the contractor's order. Those adjustments need numerous trials (at least 10 for each shape of cut & bent rebar), which ultimately increase cost due to increased scrap. The rebar fabricators also stated that commonly there are more than 20 different shapes of cut & bent rebar in each order they receive from contractors. This means that at least 200 cut & bent rebar is wasted in each lot, which approximately weigh 230 kg and cost $120. The quality manager and the sales manager of the interviewed rolling mills admitted that they dump substandard materials, which were returned by international clients due to low quality, on the domestic market rather than destroying those defective products because they have a monopoly and their customers have no way to enforce quality standards. In other words, the products they sell to the domestic customers are the scrap that does not meet the requirements stated in the specifications. Contractors could buy quality materials from mills outside Turkey, but they would pay more.

Figure 6: Computer integrated machines used by rebar fabricators

2. *Long procurement process*: Sometimes the rebar fabricators use straight rebar as a raw material for the fabrication process. The rolling mills most commonly produce rebar with a

standard length of 12 m. This causes a huge amount of waste resulting from cutting uneconomical shapes. The rebar fabricators reported that being able to procure straight rebar of each size and length whenever they are required may likely reduce lead time and improve productivity. It should be noted that the lead time for acquiring non-standard lengths of straight rebar from a rolling mill is approximately 10–15 days.

3. *Imposed large lot sizes*: The rolling mills do not sell coil rod or straight rebar in lots less than 50 tons. With no guarantee of continuous demand, rebar fabricators cannot afford the increased financing cost or the cash to invest in large inventories.

MAIN REASONS FOR ON-SITE REBAR FABRICATION PREFERENCE IN THE TURKISH CONSTRUCTION INDUSTRY

Although off-site fabrication practices of cut & bent rebar provide contractors with several advantages mentioned in the previous section, both Polat and Ballard (2003) and the interviews with practitioners revealed that on-site fabrication of cut & bent rebar is preferred in Turkey rather than off-site fabrication. The interviewed practitioners claimed that there are three major reasons for this preference. A brief description of those reasons is summarized below.

The first reason offered by the rebar fabricators is the poor coordination capability of contractors. Most Turkish contractors outsource the work to specialty contractors (subcontractors). Their major role is coordinating the subcontractors. This way of practice may seem at first glance to be consistent with the lean thinking philosophy (Womack et al. 1990, Womack and Jones 1996). However, the contractors are not willing to take responsibility for managing the entire supply chain, and they try to transfer the risk and liability of all activities associated with the sub trades to the subcontractors. For instance, a main contractor contracts out all the superstructure construction work to a main subcontractor, who undertakes the risk and liability of the superstructure construction work. The main subcontractor also contracts out the activities associated with the superstructure construction, which are preparing formwork, installing rebar, pouring concrete, to other subcontractors. The interviews with the practitioners revealed that the main contractor communicates with only the main subcontractor and does not have any relationship with the other subcontractors. In other words, the main subcontractor is responsible for coordinating its own subcontractors. Both the main contractor and the main subcontractor do not interfere with the subcontractors' ways of doing their businesses as long as everything goes fine. If something negative happens, the main contractor sues, or threatens to sue, the main subcontractor and the main subcontractor sues the subcontractors for the damages. The interviewed practitioners claimed that the subcontractors in charge of managing the entire rebar supply chain work with the same crews, who are specialized in on-site fabrication and do not have any experience in off-site fabrication, and the subcontractors are not eager to change their customary way of doing business.

The rebar fabricators reported that even when contractors do not outsource the work and take all the responsibility of completing the superstructure construction on time, they still have a strong preference for on-site fabrication of cut & bent rebar rather than off-site fabrication. The rebar fabricators claimed that the second reason for the on-site fabrication preference is the contractor's defective ordering procedure. Off-site fabrication requires reliable information flow. In other words, a contractor must prepare a purchase order or orders, which includes correct information about the quantity, diameter, length, shape and when rebar is needed on site, and must send this order to a rebar fabricator considering the fabricator's lead time. However, as the survey of Polat and Ballard (2004) and the case studies (Polat and Ballard 2003) revealed, most of the contractors experience severe problems resulting from defective ordering procedures. The uncertainties in the ordering procedure include delay in receiving purchase requisitions from site managers, mistakes in the purchase requisitions including lack of information about quantity and quality of the required rebar, delay in the approval of purchase orders by top level management, and delay in sending purchase orders to the rebar fabricator. The on-site fabrication of cut & bent rebar is more responsive to such changes and errors compared with off-site fabrication. The rebar fabricators claimed that most contractors are not aware of potential benefits of reliable information flow so they prefer on-site fabrication rather than off-site fabrication in order not to be compelled to seek ways of developing a more thorough ordering procedure.

The interviewed contractors admitted that they attempt to find new ways to overcome the problem resulting from low quality raw materials in order to reduce cost and increase profitability. They explicitly stated that they prefer on-site fabrication rather than off-site fabrication because they can fiddle the numbers on workers and scrap, thus increasing the money they receive from clients. For instance, they tell the owner that seven

workers worked in the on-site fabrication although only four workers had done so. They receive progress payments based on the inflated report. The contractors spend that extra money for the inevitable expenses that they cannot request from the owner including bribes that they pay to the municipality for permits, to policemen for security, and the control organization of the owner for allowing some of their minor mistakes. Moreover, they tell the owner that 10-15% of the purchased rebar was wasted during on-site fabrication due to cutting uneconomical shapes and workers' mistakes, and they demand material cost for the quantity augmented by that amount of waste from the owner. However, they use the residual rebar in the construction of structures such as stairs, parapets, terraces, etc., which are subject to small loads, in order to receive more disbursement in the progress payment. In other words, although only 4-7% (by weight) of the purchased rebar is wasted, they receive payment as if 10-15% of the purchased rebar were wasted. Off-site fabrication, would prevent them receiving extra money from the owner since all cost drivers including labor and material would be invoiced.

It should be noted that even though on-site fabrication of cut & bent rebar is most commonly preferred in Turkey, there are also some contractors choosing to have rebar fabricated off-site. The interviewed contractors and rebar fabricators claimed that Turkish contractors mostly prefer off-site fabrication of cut & bent rebar when they do business with a specialized party (this party may be a project management consultant, main contractor, or client), who compel them to have rebar fabricated off-site via a contractual clause. For instance, the contractor of the Ataturk Olympiad Stadium project had always preferred on-site fabrication of cut & bent rebar until that project. Yet, this contractor had rebar fabricated off-site in that project owing to the clause in the contract, by which the contractor was obligated to have rebar fabricated off-site, set by the competent French project management consultant. But, that contractor still has rebar fabricated on-site on other projects.

RECOMMENDATIONS FOR OFF-SITE FABRICATION PERFORMANCE IMPROVEMENT IN TURKEY

Although off-site fabrication of cut & bent rebar promises several advantages to contractors, there is still a strong preference for on-site fabrication of cut & bent rebar in Turkey rather than off-site fabrication as a result of factors commonly encountered in developing countries. In summary, there are mainly three aspects of on-site fabrication preference in the Turkish construction industry, which are; 1) Technical problems: The rebar fabricators experience long procurement process and imposed large lot sizes problems because of the fact that the rolling mills prefer mass production rather than lean production, 2) Managerial problems: The lack of management capability of contractors including the poor coordination capability and the defective ordering procedure is one of the main reasons for contractors' preference for on-site fabrication, and 3) Ethical problems: The rebar fabricators' problem resulting from low quality of the purchased raw materials and contractors' tendency to fiddle the numbers on workers and scrap in order to increase the money they receive from clients are the unethical attitudes.

Technical and managerial problems may likely be overcome by adopting lean thinking philosophy. Managerial problems including the contractors' failure in coordinating different subcontractors and managing the entire supply chain may likely be overcome by means of the Last Planner production control system. For instance, since look-ahead planning enables detecting and reacting to possible future problems due to the lack of coordination among different parties involved in the project, it may likely allow contractors to coordinate different subcontractors and manage the entire supply chain. Technical problems may likely be overcome by means of reducing the pool of suppliers to single-sourcing, establishing long-term business relationships with individual suppliers based on mutual trust and benefits, and involving suppliers at both pre-contract and post-contract stages in construction planning.

Individual contractors and rolling mills can help themselves by learning and applying lean construction thinking and tools. Construction industry clients can encourage their suppliers of design and construction services to develop their management capabilities. Turkish Contractors Association can provide training and education in lean construction for its members. All of these things can be done and all will help.

However, ethical problems are the most important hindrances in adopting lean thinking philosophy and implementing lean construction techniques. In that case, the best solution may be a national initiative led by the government. Improving construction industry performance is a matter of national importance and both deserves and requires government leadership in the formation of a government/university/industry initiative. The Movement for Innovation in the UK (Egan 1998) is one example of such an initiative.

CONCLUSIONS

Although off-site fabrication of cut & bent rebar provide contractors with several advantages, there are various factors that compel contractors to fabricate construction materials on-site. Those factors are especially powerful in developing countries. This study revealed that most Turkish contractors prefer on-site fabrication of cut & bent rebar rather than off-site fabrication because of the fact that on-site fabrication masks the problems resulting from the lack of management capability of contractors including the poor coordination capability and the defective ordering procedure, and it enables contractors to fiddle the numbers on workers and scrap in order to increase the money they receive from clients.

Contractors are profit-seeking organizations; hence a major aim is to minimize the total cost of a project. A study by Polat & Ballard (2005) suggests that on-site fabrication results in less cost to the contractor. Yet, that analysis is based on a number of assumptions regarding current managerial capabilities and ethical practices, and it does not take into account what the total cost of rebar in off-site fabrication would be if several 'infrastructural' changes were accomplished in the Turkish construction industry.

This study identifies the main reasons for on-site fabrication of cut & bent rebar in the Turkish construction industry. It also offers a set of recommendations for improving the performance of off-site fabrication of cut & bent rebar, which constitute an initial framework for the 'infrastructural' changes that must be accomplished in the Turkish construction industry before its participants can enjoy the benefits of lean construction.

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