Improving Construction Labor Productivity Using Automatic Rebar Tying Gun

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Abstract – Rebar tying is labor-intensive and expensive, with a high learning curve that restricts proficiency at the craft to a great deal of construction field experience. Obtaining this experience requires tasks that are taxing on the human body, often resulting in muscular and skeletal injuries. Previously, research and engineering controls for rebar tying/rod busting have been reasonably limited. The main contribution of this study is investigating the use of a new advanced technology to reduce the time, cost, and hazard associated with rebar tying. Hence, several experiments were conducted on the effectiveness of an automatic rebar tying gun by comparing the speed and cost effectiveness of this tool with the common industry practice of manually tying rebar with a spool of wire and pliers. The study results show that the automatic rebar tying gun could lower the learning curve, thereby reducing training times and minimizing redundant routines. By minimizing the amount of time invested in training employees, the possibility of saving time and money is apparent. However, risk reduction is also implied by the lessening of time invested in training employees. This is because resignations frequently happen before a return on the investment of training is produced, resulting in sunk costs. Various repetitive, often manual, movements required of workers have been observed to be reduced from the use of the rebar tying gun. The results of this study also shows that the automatic rebar tying gun has a potential to save time, money, and ergonomic liabilities without risking productivity.

Keywords – Automatic Rebar Tying; Labor Productivity; Rod Busting Process; Musculoskeletal Disorders; Construction Project

1 Introduction

Rebar tying is one of the most labor-intensive jobs in construction projects; requiring repetitive, trunk-bending motions to complete a single tie. The most common type of construction worker injury, a musculoskeletal injury, results from conditions experienced by workers tying rebar. In fact, this type of injury is predominantly seen in the rod working field [1, 2]. This can be reduced, if not eliminated, through use of state-of the-art technology [2, 3]. Hence, the primary contribution this study offers is the investigation of using an innovative technological solution to reduce the time, cost, and hazard associated with rebar tying. This rebar tying technology will not only reduce the occurrences of injury to workers, it will also increase the productivity of the time spent working.

Increasingly risky exposure to heavy material handling, repetitive movements, awkward postures, contact stresses, vibrations, and forceful exertions insidiously incur musculoskeletal damage to workers over the course of a rebar tying career. The damage experienced by the seasoned workers of today have generated a sense of urgency to innovate ways of tying rebar that prevent or reduce injuries to the seasoned workers of tomorrow (those now entering or freshly entered into the workforce).

Workers are inevitably required to assume many awkward postures while tying rebar. A University of Wisconsin study conducted by the Department of Occupational & Environmental Safety & Health showed that "25% of all workers' compensation costs are associated with construction injuries," even though construction industries account for a mere 6% of construction work. Data shows that workers in this field can have "significant risk of musculoskeletal injury." Estimates of damages related to musculoskeletal

disorders in the construction industry are “between $45 and $54 billion annually” in the United States alone [5].

With such high estimates, Choi initiated an investigation to uncover the causalities for this phenomenon. The investigation consisted of studying the physical effects rebar tying had on eleven rod workers by examining stress levels experienced by different parts of the body during traditional rebar tying. This study confirmed the “high potential risks for musculoskeletal disorders and injuries” in the rebar work of construction projects; the lower back and wrists of workers being among the most injurious areas for concern. “A guideline suggesting 15% - 30% of the maximum capability to avoid fatigue” exists, however, inevitably “65% - 92% of [rod worker’s] maximum capability exerted results in long-term injuries. Naturally, monetization is a priority in any change implemented in business, however, the health and wellness of workers in this field should also serve as a bottom line [6]. This double-bottom line philosophy has been adopted in many other industries to improve customer and employee satisfaction, ultimately resulting in increased monetization. The effects of rapid, repetitive motions of the wrists and forearms while using pliers for the traditional tying method were observed. The long-term musculoskeletal effects that traditional rebar tying can have on the trunk of a person is tested as the basis for this study. [7].

Additional research on the Biomechanical Assessment of Three Rebar Tying Techniques states in an article that construction workers specializing in highway, street, or bridge construction have incident rates “one third higher than the national average.” A study of a similar nature was conducted to see the amount of these workers that had experienced any type of musculoskeletal disorders (MSD). Of the 1,000 ironworkers, a mere 12% had no record of reporting MSD in their career. Observations revealed that while manually having to tie rebar using pliers, workers “sustained deep trunk bending and rapid and repetitive hand and wrist movements.” 94% of the time rod workers using the conventional method experienced extreme trunk flexion. Whereas, once the automated tier, extension pole included, was introduced, 83% of the time neutral flexion was experienced and moderate forward flexion was experienced 16% of the time, leaving workers in extreme flexion only 1% of the time. These problems were “greatly reduced” while using an automated tier, yet their elimination is possible by attaching the extension handle to the automatic rebar tier, allowing the worker to tie standing erect [8].

A potential reduction in the risk of developing a MSD in the trunk from rebar tying is demonstrated in this study through the analysis of workers using of a rebar tying machine versus those using conventional methods. The study made evident the hypothesized benefits of the rebar tying machine. The following section is an overview of the experiment and results.

2 Methodology and Results

Our experiment consisted of a prefabricated rebar cage with evenly spaced rebar. A technician tested two different rebar tying guns alongside the performance of an experienced traditional rod buster. The time spent by each the gun users and the rod buster was compared to create a cost analysis to determine any benefits from the rebar tying gun. The performance resulting from use of the gun was examined along with the performance demonstrated by the rod buster to provide evidence for the effect on performance resulting from the use of the gun.

The rebar cage has been designed and made for conducting this experiment in the construction lab at Lamar University (Figure 1). We prepared the rebar cage by cutting four 2X4’s to 5ft lengths, then connecting them at each end with screws. Holes were drilled on each of the cage’s sides to provide a space for the rebar to go through. The 5ft lengths of rebar were inserted into the pre-drilled holes aforementioned.

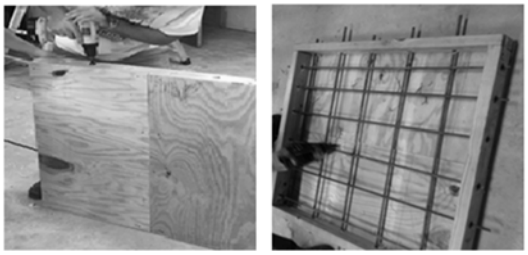

Figure 1. Rebar Cage

The rebar cage we used consisted of 2X4’s with #3 rebar spaced evenly in order to create 36 tie points. The two different types of rebar tying guns used were the RB655 with 16 gauge tie wire and the RB397 with 21 gauge wire. Our experienced rod buster used 36 gauge wires with pliers to create his ties while a timer was used to accurately record how long it took to tie the predetermined number of ties (Figure 2).

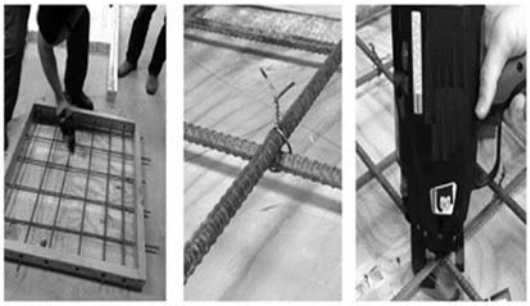

Figure 2. Lab experiment at Construction Lab (Lamar University)

The rebar tying guns were prepared to tie the allotted ties in the rebar cage, and all necessary tools and materials, such as wires and pliers, were provided for our experienced rod buster to do the same.

Our research design consisted of recording the amount of time that it took the rebar guns and the rod buster to tie 36 ties (not including actual prep time). The rebar cage was placed at ground level for all trials, and durations for each the gun users and the rod buster were recorded using a digital timer. Qualitative factors, such as each tie's tightness, were considered in performance observations as well. Thus, cost analysis calculations were performed by processing the raw quantitative and qualitative data with the wage rates listed by the Bureau of Labor Statistics to produce a numerical value that could represent the "cost" basis for our research [9].

The 16 gauge wire gun was able to tie the allotted ties in 1 minute 13 seconds, while the 21 gauge wire gun was 17 seconds quicker, recorded at 54 seconds. The experienced rod buster took 4 minutes 31 seconds to tie the same amount of ties each of the guns tied in an approximately one minute average. This shows well over a 4:1 ratio in the productivity of the guns versus that of the rod buster. Experiment conditions were the same for both gun users and the rod buster, ensuring further confidence that the deviations between the times recorded resulted directly from the tying speed of each.

However, although preparation time wasn't taken into account, it must be noted that the amount of time it takes to feed a new roll of wire into the guns can be reasonably large if operators do not have proper experience. The time variance for feeding the roll into the gun ranged from 1 minute to 6 minutes depending on the experience of the feeder. Another problematic observation of the guns' use was that the feeding process produces increasing waste with decreasing feeder experience, varying from 2 inches to almost 2 feet. These variance values were observed visibly during the experiment. Furthermore, it was noted that increased tightness and waste reduction achieved by rebar guns was visibly lower (excluding the waste produced during feeding).

Both the cost comparison (Figure 4) and time comparison (Figure 3) charts were developed using data for one rod buster manually tying two #3 rebar, and a rod buster operating each gun tying the same.

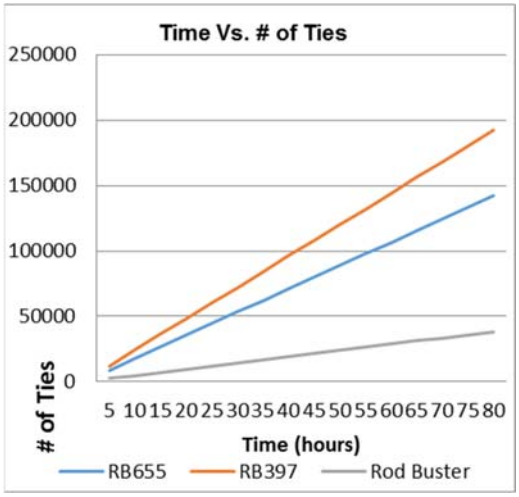

Figure 3. Time Comparison

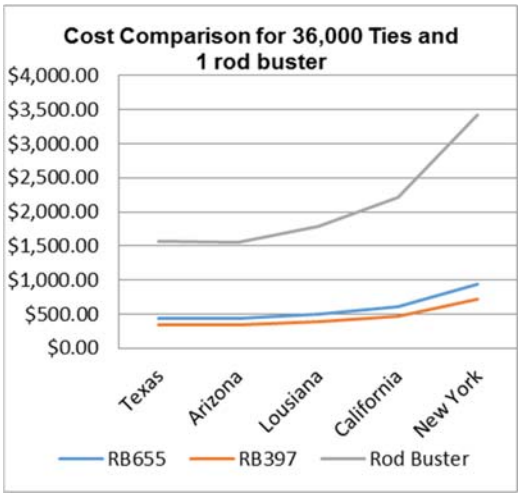

Figure 4. Cost Comparison

As can be observed from the graphs, the rebar tying guns offer a clear advantage when it comes to cost and time savings. The average cost of using the rebar tying guns for tying the set number of 36,000 ties is approximately 4 times less than the traditional method of tying rebar with pliers. Also, the amount of ties that can be made with the rebar tying guns is drastically higher per a set time. For example, at the 40 hour mark a rod buster operating an RB655 gun will tie 71,013 ties, and

one with the RB397 will tie 96,000 ties. On the other hand, a rod buster following the traditional method of using pliers will only tie 19,129 ties.

As mentioned earlier, preparation times were not counted towards our calculations, and were found to increase with lacking experience. Thus, to achieve the results shown in this study there should be some training before rod busters use a rebar tying gun. This will reduce time consuming problems associated with using the gun in operations. In our experiment, one of the attempts at feeding a new coil into a gun posed problems that took the demonstrator approximately 6 minutes to finish.

The rebar tying guns also demonstrated limited capability in tight spaces. However, our observations have led us to conclude that tying rebar in spaces of such size is not a typical demand of most construction projects. In any case, the rod buster using the gun may need to stop and tie these few ties with unusually difficult accessibility.

The average price for an automatic rebar tying gun is approximately $2500. The rebar tying gun training takes approximately 30 minutes, which includes to train a person to replace the wire and disassemble any parts that does not void the 2-year warranty period. The initial costs of the guns were not calculated into our data, largely because this cost will be negligible over the useful life of the gun. The medical benefits for the rod buster and rod buster's employer alone justify the adoption of using these guns as a standard for the construction industry; if the optional extension is incorporated with the guns, the rod busters will need to bend over less which further reduces the risk of back injuries.

3 Discussion

Through our research it appears that the rebar tying gun is more efficient than traditional rebar tying. The costs of the rebar gun is easily offset by the productivity achieved by larger rebar tying jobs, such as those done in roadwork or concrete piling construction, where a large number of ties are required. The higher the volume of ties, the greater the benefits of the rebar tying gun will be. This implies that the gun may not be justifiable economically for jobs of a smaller scale. However, the safety benefits remain a motivating factor for these smaller project contractors to consider. The cost of the gun can seem unconventional, but this product has a high potential for value-added with a reasonable payback period.

The advantages of using an automatic rebar tying gun are identified in both road and beam construction. The average rodman can tie approximately 1,775 ties and use 13.7 pounds of tying material in an hour while using an automatic tying gun in road construction. The average rodman in road construction using the traditional method can only tie approximately 448 ties and use 21.2 pounds of tying material in an hour. This considerable difference is due both to the ease of creating a tie with the automatic rebar tying gun. In the traditional method the rodman has to actually lift the rebar at the point where the tie will be located and then commence the manual tying, taking up extra time.

Based on our results, the rebar tying guns are more efficient than the traditional tying method. However, our results came from experimentation in a relatively trivial and controlled environment, a small prefabricated box with evenly spaced and elevated rebar. Hence, the box could have failed to simulate the real world applications of the rebar tying gun. The test did not take into consideration larger scaled rebar tying jobs that would incorporate movement and fatigue.

Research was limited by this factor of size, as they were not conducted on a large scale. Another limiting factor was the level of realism in the conditions in which the experiment was conducted; a more realistic trial is necessary to truly evaluate the viability of these guns on a larger scale. This inhibited results from reflecting long-term usage and effectiveness of the rebar tying gun. Future tests should include a longer trial period in a real world setting with a full project or foundation to test the timeliness and effectiveness of each tie.

The research that we conducted did not determine the strength of each tie of the rebar. Due to the different types of ties that can be accomplished with hand tying, the traditional rebar tying method supposedly has a tie with greater strength than that of a rebar tying gun, which is limited to one type of tie. This leads to another disadvantage of using the gun encountered in certain types of formwork where regulations restrict the use of the gun due to the requiring of a specific tie that only hand tying it is capable of. Future tests should confirm the strength of each tie done by hand or the gun, as well as the failure rate of each tie.

It is recommended to perform a weekly cleaning of the debris such as dirt or dust from the prongs of the rebar tier with a simple brush to prevent build up and clogging of the wire feeding mechanism. Cleaning could be required more frequently depending on the amount used and the conditions that the gun is exposed too.

Limitations to the rebar guns were not tested. The experts noted that the gun is unable to tie rebar consistently and tightly if the tie has to be tied on an upright surface or overhead. This was not tested in our research, and also should be included in future testing.

4 Conclusion

An automatic rebar tying gun could eliminate some time spent training and executing repetitive motions. It also has the possibility of saving time and money by reducing

man hours while increasing productivity. Also, since it eliminates much of the repetitive, often heavy, exertions that are normally employed by rod busters, it could reduce health risks in the rod busting community (especially if it is used with the optional extension bar). We will conduct our experiment by comparing the speed and cost effectiveness of this tool with the normal area practices, which include manually tying the rebar with pliers and a wire spool. In our study, we found that the rebar tying machine could tie two ties to an experienced rod buster's one. This advantage can be observed in day-to- day activities in the work place. The machine exhibits an optimal utility of its performance to be in the afternoon when rod busters are burnt out after intensive physical activity. This product could not only save time and money, it also has the potential to increase productivity, and therefore profitability, all the while reducing risks of injury to the long-term and short-term health of employees.

5 Acknowledgement

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