Quantifying MEPFP Mass-Timber Trade Efficiency Through Vertical Mechanical Fastener Analysis

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Abstract

Touted attributes of mass-timber structures include its efficiency in both erection and labor productivity. These efficiencies are a result of differing methods, induced by varying contractors, and are impacted by site specific variables. This study explores efficiency related to overhead fastener applications installed by MEPFP trades. Fastener installation time in an overhead rebar reinforced concrete beam is compared to that installed in a mass-timber structural beam to determine efficiency disparities (if any). Two sets of fasteners are compared in the differing materials: one for heavy and the other for light duty applications. A total of sixty fasteners were installed, consisting of two sets of fasteners, installed in both concrete and mass-timber. Results were analyzed with two independent t-tests to determine statistical significance and mean difference between fastener and material type. The study found that heavy-duty conventional overhead concrete fastener installation takes significantly longer (Fastener A-Conc. $M=12.82$ seconds) than mass-timber fastener installation (Fastener A-MT. $M=1.01$ seconds), $t(26)=38.72$, $p=<.001$. Additionally, light-duty fasteners share similar results in concrete (Fastener B-Conc. $M=12.18$ seconds) compared to mass-timber (Fastener B-MT $M=2.32$ seconds) conditions; $t(23)=33.56$, $p=<.001$. This study provides evidence that mass-timber offers significant time savings per each overhead fastener installation, when compared to traditional concrete structures. These results can be used for construction planning, productivity rates databases, and cost analysis.

Keywords: mass timber, MEPFP, labor productivity, fastener

1 Introduction

Commercial mass timber (MT) structures are proliferating in every corner of the United States. By June 2023, there were 1,860 multi-family, commercial, or institutional mass timber projects in progress, or constructed. The spread of this methodology is attributed to several factors including the rising demand for more sustainable materials and the continual pursuit for increasing efficiency in the construction industry. Mass timber proponents have argued that this methodology increases efficiency, it is a faster construction method, and it is a more sustainable alternative to the other traditional materials (concrete and steel) (Mirando & Onsarigo, 2022; Harte, 2017; Kremer & Symmons, 2015). These authors have argued that MT is not only faster to erect, but also beneficial to subsequent trades. For example, CLT panels can be pre-engineered, fabricated and delivered with mechanical, electrical, plumbing and fire protection (MEPFP) penetrations (see Figure 1) eradicating the need for on-site drilling. It is also faster and easier to install MEPFP fasteners in wood than other alternative materials. While this argument has been made in literature, there is no scientific study conducted to test that claim and give a proven and reliable estimate of the efficiency improvements that MT affords. This study compares the production rates for installing MEPFP fasteners for threaded rod hangers in mass timber and reinforced concrete.

Figure 1. CLT Ceiling panel with pre-drilled penetrations

2 Overview of Mass Timber

A solid piece of lumber typically has critical strength-limiting defects such as knots, grain deviations, splits, checks, or decay, which tend to concentrate in a single area of the lumber, making that part of the lumber the weak spot and where the wood is most likely to fail. These defects make lumber structurally unpredictable and, consequently, difficult to design with, especially when high loads are involved. Engineered wood products are designed to distribute these weak spots across the entire wood, resulting in a stronger product with predictable strength characteristics. Engineered Wood Products include structural building materials such as plywood, oriented strand board (OSB), laminated veneer lumber (LVL), wooden I-joists, and mass timber. Massive or “mass” timber is a category of framing styles typically characterized using large solid engineered wood panels for wall, floor, and roof construction. Mass timber consists of multiple solid wood panels nailed or glued together, providing exceptional strength and stability. There are various types of mass timber including cross-laminated timber (CLT), nail-laminated timber (NLT), glued-laminated timber (GLT), dowel-laminated timber (DLT) and structural composite lumber (SCL). The ability of these engineered lumber to carry large loads has made it possible to use mass timber for construction of larger and more complex structures, including high-rise buildings. Figure 2 is a picture from a project that utilized glued-laminated timber for its beams and columns, and cross-laminated timber for its floor panels.

Figure 2. INTRO Cleveland

3 MEPFP Trades

It is common construction knowledge that the critical path in construction projects always includes mechanical, electrical, plumbing, and fire protection contractors (MEPFP) (when they are specified to be included), or some element of those combined trades. These special sets of trades install critical systems in the structure that have a big impact on peripheral trades as well. Subsequent drywall and other finish contractors require the timely completion of these systems to begin their work. This highlights the importance and impact these trades have on successful completion of commercial construction projects and provides the perfect place to start analyzing efficiency. This study focuses on these critical systems trades that require the installation of overhead support systems. Examples include ductwork strapping, fire protection line hangers, electrical/fire alarm conduits, cable harnesses, plumbing waste and supply lines, cable trays, and more. Consider (Figure 3), taken from the test area, which shows how elaborate and numerous overhead systems can be. The trades that install these systems have critical importance to driving efficiency on the project.

Figure 3. Overhead MEPFP Systems

Competent project teams look for ways to positively impact critical path line items on their projects. What makes critical path items so important is the effect they have on the overall project schedule. A reduction in the duration of a critical path activity often translates to a reduction in the overall duration of the project. As mentioned above, MEPFP trades are often of the critical path of construction schedules and are consistently involved throughout the construction phase. Additionally, due to the specialized nature of their work, these skilled craftsmen are some of the highest paid trades on construction jobsites. The unique makeup and specialized requirements of MEPFP contractors makes them critical to project success. Efficiency at the MEPFP level can have major positive effects on commercial construction projects; hence the focus of this study.

4 Methodology

The main purpose of this study was to determine the effect of mass timber construction on efficiency of MEPFP fasteners installations. To achieve this, the study compared productivity for the installation of fasteners for threaded rod hangers in both steel-reinforced concrete ceilings and cross-laminated timber (CLT) structure. This study utilized an observational approach to gather field installation data on the jobsite. The team observed sixty successful installations of overhead fasteners in the two material types and recorded the time of each installation. This process is explained in detail in the data collection section. Once the data was collected through the observational approach, it was analyzed using SPSS as described in the data analysis section.

4.1 Purpose and research design

It should be noted that the research design was grounded in replicating field conditions as closely as possible. Input from the union foreman installing the fasteners was integral in understanding their installation process, tools used, and typical issues. The team met prior to the installation to get an understanding of the industry's process, different tools that are utilized, fastener types, and processes that critical trades go through. Choosing validation methods in construction research can be challenging for several reasons, especially since humans are involved in every aspect of construction projects (Liu, Shahi, Haas, Goodrum, & Caldas, 2014). Using the union foreman's experience of over seven years, a typical overhead installation process was replicated.

The main purpose of this study was to determine the effect of mass timber construction on efficiency of MEP installations. To achieve this, the study utilized an observational case study approach and available statistical tools to compare productivity of installing threaded rod hanger fasteners in both reinforced concrete and cross-laminated timber ceilings. There are up to seven types of observational studies, which can be used independently, or in varying combinations. This study deployed (and aligned best with) a structured observational case study, involving a structured environment that was more controlled than the natural environment, but that closely mimicked actual field conditions. The study differs from an experimental study in the fact that the researchers did not want to influence or intervene with the installation process, simply observed, and recorded the process.

Two identical spaces in the same building, one with a concrete ceiling and the other with mass timber (cross-laminated timber) ceiling, were used to conduct the experiment. A total of 60 threaded rod hanger fasteners were installed:

1. Fifteen (15) heavy-duty fasteners were installed in both concrete and CLT ceilings.
2. Fifteen (15) light-duty fasteners were installed in both concrete and CLT ceilings.

Fasteners in concrete were installed using a dual-motion process: 1. pre-drilling and 2. installing the fastener while those in mass timber utilized a single-motion process. Both processes were timed and tracked using video recording cameras and a stopwatch. Data collected is described in detail in the following subsection on data collection. Independent-samples *t* test was used to analyze the data to determine whether there is a statistically significant difference between installing fasteners in concrete and mass timber. The chosen *t* test is described in detail in the subsection on data analysis.

4.2 Data Collection

4.2.1 Instrument

Data for this study was collected through observation. Two video cameras with time and date stamps were used to capture the installation processes. In addition to this, two observers documented the times for each fastener installation using a stopwatch. In the first (Fastener A-Heavy-Duty) concrete application, two observers captured time data from the foreman installing the first fifteen (15) fasteners (see Figure 4). The stopwatch was depressed when the pre-drilling started, and timing was concluded when the fastener was fully seated in the pre-drilled hole. Data for installation on the mass timber beam was collected in the same exact manner to maintain consistency. This process was repeated for Fastener B-Light-Duty.

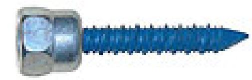
Figure 4. Foreman installing ⅜" fasteners into the bottom on the mass-timber beam.

The data recorded on paper and video formats was harmonized and transferred to an excel spreadsheet and the variables were coded: material (Concrete - 0, MT - 1), Fastener type (Fastener A - 0, Fastener B - 1), and installation time (seconds). No outliers or missing/inaccurate data points were detected from visual inspection and the data was grouped and sorted for import into SPSS. See Appendix B for the raw data.

4.2.2 Fastener Types

The fastener types used in this study deserve detailed breakdown of the exact specification, size, and imagery to show the vertical hanger system used. There are several products available on the market, and distinguishing the fasteners used in this study is important, as differing types/brands may elicit different results. Input from the union foreman was integral in understanding the different fastener types and in selecting the correct and comparable types to use in this study. The contractor recommended the "Sammy" system because of its simplicity and reliability. See Appendix A for complete detail on the selected fasteners.

Table 1. Fastener Types used in this Study

Fastener Name/Model	Size	Material	Light/Heavy	Image
Fastener A – No. 8059957	5/16” D X 1 ¾” L	Concrete	Heavy	
Fastener A – No. 8008957	¼” D X 2” L	Mass-Timber	Heavy	
Fastener B – No. 51542	¼” D X 1 ¼” L	Concrete	Light	
Fastener B – No. 31078	#8-15 X 1 ½” L	Mass-Timber	Light	

* Heavy-duty ≥ 50” W duct, Light-duty <50” W duct

4.3 Data Analysis

The collected data was analyzed using SPSS (Statistical Package for the Social Sciences) software program. Descriptive statistics, which encapsulate the measures of central tendency, variability, and frequency distribution, enable us to understand the primary characteristics of the dataset. As mentioned above, a two-sample (independent) *t* test was also used to determine whether there is a significant difference in productivity when installing fasteners in concrete versus mass timber (CLT). This inferential statistical test determines whether there is a statistically significant difference between the means in two unrelated groups (Laerd, 2023). For the two-sample *t* test, the null and alternative hypotheses below were used.

H_0: $\mu_1 = \mu_2$ (mean for installation in CLT is equal to mean for installation in concrete).

H_1: $\mu_1 < \mu_2$ (mean for installation in CLT is less than mean for installation in concrete).

This study also used prevailing wage rates to estimate the cost savings resultant of the efficiency improvements. Since the test project was constructed with union plumbers, sheet metal workers, boilermakers, electricians, etcetera, averaging approximately $71.34 per hour (ACT Ohio, 2023), this estimated labor rate was used in the cost analysis.

4.4 Simulated Cost Saving

The total cost savings on fastener installation in a commercial mass timber project were estimated. The following assumptions were made:

- Building size is 512,000 square feet. This is the actual size of the mass timber building selected for the study. The building is 9 stories, over 180 rooms, and is in Cuyahoga County, Ohio
- 0.4 fasteners per square foot for commercial buildings: both light- and heavy-duty. The number of overhead fastener installations in a project is dependent on numerous factors including size and weight of overhead systems, scope, end use, existing conditions, design, and owner need. However, the estimate used in this study was provided by the selected project's development team who determined the numbers from the BIM model showing overhead fastener counts and location.
- Average prevailing wage rates for two MEPFP trades in Cuyahoga County, Ohio were used: Plumber ($70.99 per hour) and Sheet Metal Worker ($71.68 per hour) (ACT Ohio, 2023).

5 Findings

Inspection of the Q-Q Plots showed normal distribution for both groups and that there was homogeneity of variance as assessed by Levene's Test for Equality of Variances (see Figures 5 and 6). The independent t-tests were run on the data with a 95% confidence interval (CI) for the mean difference. Box plots for both samples identified outliers that were analyzed and removed. For instance, Fastener A exhibited a couple of outliers (Figure 5) consequently, installation 1 and 17 were removed from each material installation type. These outliers are a result of either human error and/or mechanical failure. In one case a tap-con sheared from over tension while in the other the installer fumbled the fastener.

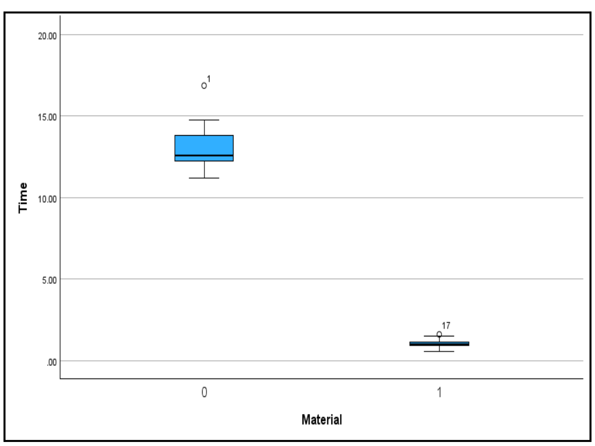


Figure 5. Fastener A Heavy-Duty Boxplot Comparison (Note: 0=Concrete and 1=Mass Timber)

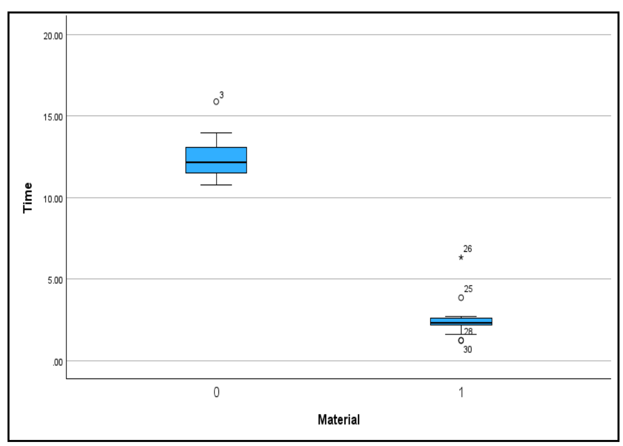


Figure 6. Fastener B Light-Duty Boxplot Comparison (Note: 0=Concrete and 1=Mass Timber)

5.1 *t*-tests

Two independent-samples t-tests were conducted to compare differing fastener installation speeds, in both concrete and mass-timber material applications. The first independent-samples t-test (Fastener A) was conducted to compare installation time for fasteners in concrete and mass-timber conditions. Test A produced significant difference in the results for heavy-duty fasteners in concrete (M=12.82, SD=1.11) and mass-timber (M=1.01, SD=.23) conditions; t(26)=38.72, p=<.001. These results suggest that mass-timber fastener installation in the heavy-duty category is significantly quicker than concrete, by a mean difference of 11.08 seconds.

The second test was conducted to compare installation time for fasteners in concrete and mass-timber conditions when light-duty fasteners (Fastener B) are used. This fastener size is used for hanging smaller items, and lighter items than those for Fastener A. Test B produced significant difference in the results for light-duty fasteners in concrete (M=12.18, SD=.93) and mass-timber (M=2.32, SD=.30) conditions; t(23)=33.56, p=<.001. These results suggest that mass-timber installation in the smaller size, for lighter applications, is also significantly quicker than concrete, by a mean difference of 9.85 seconds.

5.2 Cost Saving

Using the quantities provided by the BIM model and development team, it was determined the commercial mass timber project had approximately 0.4 fasteners per square foot. This translated to 204,800 overhead fasteners for our selected building (512,000 square feet). Some of those fasteners were heavy-duty and some were light-duty (See figure 7) presenting an average time savings of 10.5 seconds. The average cost of two different MEPFP trades (plumbers at $70.99 per hour and sheet metal workers at $71.68 per hour) was used in the estimate. The total direct time savings were calculated to be **595.34**-man hours, which translates to $**42,468.74** direct cost savings.

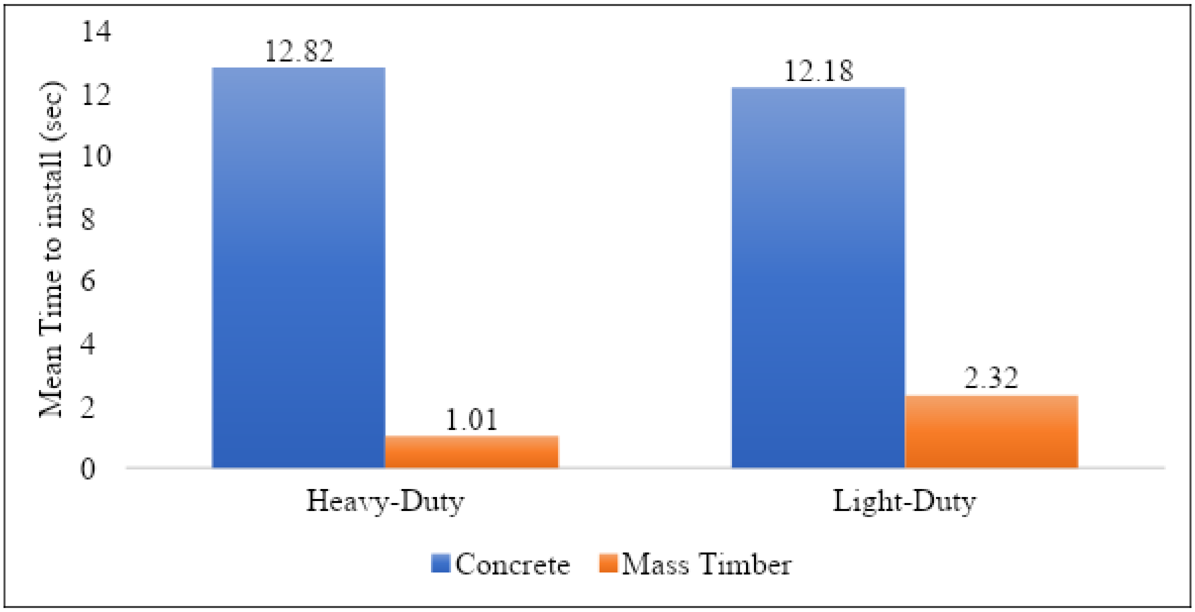


Figure 7. Mean Installation Time for Fasteners in Concrete and Mass Timber

Peripheral cost savings should also be considered when estimating installation time for mass timber projects. For example, installers will not require costly silica mitigating hammer drills that cost $750 each, plus costly diamond tipped drill bits. Using a conservative estimate of ten hammer drills, across the MEPFP trades, equates to $7,500, plus $3,500 in drill bits for the entire project, totaling $11,000.00. Combined with direct labor savings, the total direct costs can be calculated as approximately **$53,468.74.**

6 Discussion, Example, Recommendations, and Conclusion

1.1 Discussion

This study identified important information relative to mass-timber production rates. The following outcomes relative to this study will be outlined and discussed here. First, material type has a significant impact on fastener efficiency. Secondly, fastener size and type can have an impact on productivity. Thirdly, mass timber is a better material to work with from an ergonomic perspective, translating to better health and longevity for the construction workers. Fourthly, installations in concrete generate considerably more noise, dust and debris which have associated environmental, health, and cleaning costs. The fifth point is that there are risks involved with drilling in reinforced concrete as opposed to installing fasteners in mass timber. Finally, there are cost savings that can be realized when installing fasteners in mass timber as opposed to concrete.

1.1.1 Material type

Material type has a significant impact on fastener installation efficiency. While this is not groundbreaking, the differences in installation time is incredibly large. For the heavy-duty fasteners (fastener A), installation in mass timber (1.01 sec) was over 12 times faster than installation in concrete (12.82 sec) which included pre-drilling and insertion of a tapcon. For the light-duty fasteners (fastener B), installation in mass timber (2.32 sec) was over five times faster than installation in reinforced concrete (12.18 sec). While a difference in efficiency certainly was hypothesized, the time disparity was much greater than anticipated. One of the reasons for the significant difference in time is the fact that mass timber installations did not require predrilling while concrete installation did. This two-step process, coupled with the fact that the installer used two separate tools (a drilling tool and a driving tool) and had to switch between the two with each installation, are the primary reasons why the installation in reinforced concrete took much longer than in mass timber.

1.1.2 Fastener type and size

The type and size of fastener used can have an impact on the level of productivity in mass timber projects. In this study, there was a determined speed difference when installing smaller (B) fasteners in the wood versus installing thicker screws (A). The difference is not as substantial as the one between mass timber and concrete, but still represents a 56% (1.01 sec for fastener A vs 2.32 sec for fastener B) decrease in production when installing the light-duty fasteners as opposed to the heavy-duty fasteners. This slower productivity is attributed to the installer often fumbling with smaller screw sizes and having to slow pre-drill to get the fastener started. The larger (A) screw afforded better grip and were consequently installed without as many slips or miscues. Evaluating the fastener type during the pre-construction phase of the project is critical to ensuring efficiency in installation.

1.1.3 Ergonomics on the jobsite

Construction has consistently been ranked as one of the most dangerous industries, not just because of the comparatively higher death rates, but also because of the number of injuries involved (National Safety Council, 2023). A substantial number of these are ergonomic injuries including back, hand, neck, and shoulder injuries. Employers have an obligation to protect their employees by providing a safe and healthy workplace. One of the suggested ways employers can do this is by applying ergonomic principles (OSHA, 2023) which may include methods and materials that promote these practices. This study shows that fastener installation in MT is ergonomically superior to concrete for several reasons. First, the installer only needs one tool for MT applications. Typically, this is in the form of an impact driver, with a hex head. Compared to concrete applications which require a much heavier, rotary hammer drill that can weigh in excess of 15 pounds, in addition to the impact driver. So not only does the installer benefit from less overhead motion in that no pre-drill is required, it is less demanding to penetrate as represented by the time difference outlined in the study. Certainly, the wear and tear on a worker’s body is more difficult to quantify, however, it cannot be argued that less overhead repetitions, less demanding penetration requirements, and the use of lighter equipment have a positive impact on efficiency and health of the construction worker.

1.1.4 Other health and environmental considerations

Concrete penetrations create more noise, dust, and debris than wood surfaces. Pre-drilling into post-tension concrete often creates plumes of dangerous silica debris that can cause respiratory illnesses (Dement, et al., 2003). Modern tools with dust collectors, and respiratory protection can help mitigate inhalation risk at the cost of added weight and added annoyance. And even with the use of vacuum dust control measures, construction workers are still exposed to respirable silica

(Cooper, Susi, & Rempel, 2012). The use of hammer drills for pre-drilling penetrations in concrete has also been known to radiate noise of 85 decibels or higher to the adjacent room, enough to cause hearing impairment (Carty, et al., 2017). These health and environmental issues simply do not exist when working with mass timber surfaces.

1.1.5 Other associated risks

There is significantly more risk in penetrating reinforced concrete overhead slabs and beams. Firstly, both post-tensioned cables and rebar reinforcement are at risk of being touched by drill bits and fasteners. The fasteners in this study penetrated up to 2", which was right around where the lower reinforcement steel bars would be placed. In order to mitigate the risk of hitting a cable, we ran our test on the bottom of a rebar reinforced beam. However, one fastener hit a piece of rebar and sheared off the tapcon head from the force. Not only are cables and rebar at risk for being interfered with, conduit, in-slab heating systems and other hidden components, if not coordinated, could cause major issues. Those risks are not present in a mass timber setting as these components are not compiled within the flooring or beam systems.

1.1.6 Cost Saving

Based on this study, there is evidence of direct cost savings when installing MEPFP services in mass timber. Determination of the number of fasteners needed in a project can help estimate the direct cost savings, however these direct savings are only a proportion of the overall benefits to the project cost and schedule. There are potential resultant savings to subsequent activities and trades. It is also important to note that there are aspects of the job that are more difficult to quantify including the abandonment of respiratory protection and expensive silica mitigating techniques/tools in mass-timber applications. Similarly, reduced ergonomic impact should translate to less injuries.

1.2 Recommendations

Project teams should pay attention to all aspects of the building process including the small details, especially in the case of processes that are on the critical path. This study provides data showing increased overhead fastener installation rates on mass-timber structures. Teams can use this information in several ways. This section outlines recommendations from the findings sections that could benefit the reader.

Teams should dedicate pre-construction resources to evaluating MEPFP fastener type and quantity to discuss time savings, potential monetary concessions from installation subcontractors, and to determine the impact fastener efficiency will have on the schedule. Fastener submittal data should not be rubber stamped from the construction manager as it often is, as this little detail could have cost and schedule ramifications, previously overlooked. Furthermore, integration of this data into a BIM model (where applicable) may help coordination and the estimator's ability to provide more accurate cost estimates.

Further research is required to understand the efficiencies (and potential inefficiencies) on mass-timber protects. Benefits of manpower efficiency exist beyond the reaches of MEPFP fasteners. A multitude of other aspects that are similar and/or related to this study can be examined. Another area that needs extensive research is health, safety, and ergonomic studies relative to overhead installation of these systems. Mass-timber structures immediately remove 50% of overhead penetrations, in friendlier material, with less payload on installers, and with less silica debris. Outside of the direct quantifiable costs, hidden costs like accidents and injuries should be examined and quantified.

1.3 Conclusion

Seconds add up, especially on the scale of commercial, high-rise construction. This study identified several important findings relative to mass-timber's efficiency in the critical MEPFP trades. The study determined that mass-timber surfaces provide a faster installation process in both fastener sizes, when compared to post-tension concrete. Furthermore, risk of damaging bits, fasteners, or hitting post-tension cables is mitigated in mass-timber applications. Readers can use the findings presented here for planning, cost, and scheduling purposes. Importantly, manpower efficiency rates can be added to historical cost databases. Project teams who invest pre-construction resources in evaluating fastener details and locations in mass-timber structures can benefit from the statistically significant data presented here.

2 References

ACT Ohio. (2023, September 17). *Cuyahoga County Prevailing Wage Rates*. Retrieved from Afiliated Construction Trades (ACT) Ohio: https://www.actohio.org/issues/prevailing-wage/by-county/cuyahoga-county/

Carty, P., Cooper, M. R., Barr, A., Neitzel, R. L., Balmes, J., & Rempel, D. (2017). The Effects of Bit Wear on Respirable Silica Dust, Noise and Productivity: A Hammer Drill Bench Study. *Annals of Work Exposures and Health, 61*(6), 700-710.

Cooper, M. R., Susi, P., & Rempel, D. (2012). Evaluation and control of respirable silica exposure during lateral drilling of concrete. *Journal of Occupational and Environmental Hygiene, 9*(2), D35-D41.

Dement, J. M., Welch, L., Bingham, E., Cameron, B., Rice, C., Quinn, P., & Ringen, K. (2003). Surveillance of Respiratory Diseases Among Construction and Trade Workers at Department of Energy Nuclear Sites. *American Journal of Industrial Medicine, 43*, 559-573.

Harte, A. M. (2017). Mass timber–the emergence of a modern construction material. *Journal of Structural Integrity and Maintenance, 2*(3), 121-132.

Kremer, P. D., & Symmons, M. A. (2015). Mass timber construction as an alternative to concrete and steel in the Australia building industry: a PESTEL evaluation of the potential. *International Wood Products Journal, 6*(3), 138-147.

Laerd. (2023, September 19). *Independent t-test for two samples*. Retrieved from Laerd Statistics: https://statistics.laerd.com/statistical-guides/independent-t-test-statistical-guide.php

Liu, J., Shahi, A., Haas, C. T., Goodrum, P., & Caldas, C. H. (2014). Validation methodologies and their impact in construction productivity research. *Journal of Construction Engineering and Management, 140*(10). Retrieved from https://doi.org/10.1061/(asce)co.1943-7862.

Mirando, A., & Onsarigo, L. (2022). Construction Productivity Comparison Between Cast-in-Place Concrete and Mass-Timber Framing: A Case Study of the Nation's Largest Mass-Timber Building. *EPiC Series in Built Environment, 3*, 443-451.

National Safety Council. (2023, September 19). *Industryr Incidence and Rates*. Retrieved from NSC Injury Facts: https://injuryfacts.nsc.org/

OSHA. (2023, September 19). *Ergonomics*. Retrieved from Occupational Safety and Health Administration: https://www.osha.gov/ergonomics

Appendix A - Fastener Submittal

the K company inc.

"Service Not Excuses"

Project:	**Kent State University Fastener Study**
Date:	July 28, 2023
Owner:	Harbor-bay Ventures
Contractor:	The K Company, Inc.
Specification Section:	Fastener Product Data

Contractor remarks:

1. For duct work under 50" wide:
   a. CLT - Pg.2 Part No. 31078
   b. Concrete - Pg. 3 Part No. 51542
2. For duct work exceeding 50" wide
   a. CLT - Pg.4 Part No. 8008957
   b. Concrete - Pg.5 Part No.8059957
3. For equipment or kitchen hoods exceeding 1,000lbs:
   a. CLT - Pg.4 Part No. 8013925
   b. Concrete - Pg. 5 Part No. 8060925

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Sheet Metal Screws Cont.

FNL Sharp Point Sheet Metal Screws

	#8	#10
	Indented Hex Washer	Indented Hex Washer
	Hex Slotted	Hex Slotted
	Zinc	Zinc
Length	Part No.	Part No.
1/2"	31066	31090
5/8"	31068	-
3/4"	31070	31094
1"	31074	31098
1-1/4"	31076	31100
1-1/2"	31078	31102
1-5/8"	-	-
1-3/4"	-	31104
2"	31082	31106

Mach1 Pierce Point Sheet Metal Screw

	#8	#10
	Indented Hex Washer	
	Hex Slotted	
	Zinc	
Length	Part No.	Part No.
1/2"	31477	31484
3/4"	31479	31485
1"	31480	31486
1-1/2"	31482	-
2"	31483	-

FNL Speed Point Painted Sheet Metal Screws

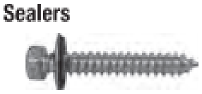
Head - Indented Hex Washer Drive - Hex Slotted				
		Zinc		
		Brown	Cocoa Brown	White
Diameter	Length	Part No.	Part No.	Part No.
#6	3/8"	11100299	11100300	11100298
#7	1/2"	11100302	11100303	11100301
#8	1/2"	11100305	11100306	11100304
#8	3/4"	31085	-	31084
#8	1"	-	-	31086
#8	1-1/2"	11100307	11100308	31087
#10	1-1/2"	11100310	11100311	11100309

Wood Sealer Screws

Non-walking sharp gimlet point for fast material engagement. Dual sealing bonded washer prevents leaks. Vulcanized bonding of washer eliminates separation of EPDM from the metal backing. High Hat Hex Washer Head for driving stability.

Diameter - #9 Head - High Indented Hex Washer Drive - Hex - Unslotted													
	ACQ Compatible 1000 Hour Coating												
	Barn Red	Bright White	Brown	Charcoal Gray	Clay	Cocoa Brown	Evergreen	Gray Wood	Light Gray	Light Stone	Plain	Polar White	White
Length	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.
1"	11100253	-	11100257	11100260	11100256	11100258	11100254		11100259	11100255	31931	11100252	31932
1-1/2"	11100262	-	11100266	11100269	-	11100267	11100263	11100265	11100268	11100264	31933	11100261	31934
2"	11100271	-	11100275	11100278	11100274	11100276	11100272	-	11100277	11100273	31935	11100270	31936
2-1/2"	11100280	-	11100284	11100287	11100283	11100285	11100281	-	11100286	11100282	31937	11100279	31938
3"	11100290	11100288	11100294	11100297	11100293	11100295	11100291	-	11100296	11100292	31939	11100289	-

Tapping Screw Sealers

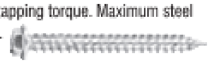


An EPDM rubber washer bonded to a steel washer compresses to form a weather tight seal as you drive these unslotted screws; Type A Point. Also known as tap screws, they are ideal for metal-to-metal fastening or metal-to-wood fastening. Length is measured from under head.

Head - Hex Washer Drive - Hex - Unslotted		
	#14	#17
	Zinc	
Length	Part No.	Part No.
3/4"	31902	31917
1"	31903	31916
1-1/4"	31904	-
1-1/2"	31905	31918
1-3/4"	31906	-
2"	31907	-
2-1/2"	31908	-
3"	31909	-
3-1/2"	31910	-
4"	31911	-
5"	31913	-
6"	31915	-

ITW Buildex TRUGRIP™ Metal To Wood Fasteners

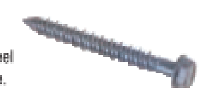
Features a non-walking sharp point for fast material engagement and a high head HWH for driving stability. Climaseal finish provides excellent corrosion resistance and lower tapping torque. Maximum steel thickness is 18 gauge.



Head - Hex Washer Drive - Hex - Unslotted		
		Climaseal®
Diameter	Length	Part No.
#9	1"	0131192
#9	1-1/2"	0131193
#9	2"	0131194
#9	2-1/2"	0131195
#9	3"	0131196
#12	3/4"	0131197

ITW Buildex SCOTS® TRUGRIP™

Features a 300 series stainless steel head with integral washer and a #10 Hi-Lo thread for greater pullout in wood. The A.P.T. point provides fast cutting, easier tapping and pigtail reduction. Climaseal finish provides excellent corrosion resistance and lower tapping torque. Maximum steel thickness is 18 gauge.



Head - Hex Washer Drive - Hex - Unslotted		
		Climaseal®
Diameter	Length	Part No.
#10	1"	0131204
#10	1-1/2"	0131205
#12	3/4"	0131207

FNL Bi-Metal Screws with Bonded Sealing Washer

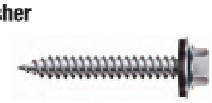
Composed of two metals, where the body of the screw is made of stainless steel and the drill point is a hardened steel.

- Hardened point for more effective self-drilling
- Screw body is made of 304 Stainless Steel for corrosion resistance and increased torsional strength
- Zinc plating provides added corrosion resistance and uniform appearance
- Compatible with ACQ treated lumber

		Hex Washer	Pan
		Hex	Phillips
		Zinc with Wax	
Diameter	Length	Part No.	Part No.
#9	1"	11342399	11342403
#9	1-1/2"	11342400	11342404
#9	2"	11342401	11342405
#9	2-1/2"	11342402	11342406

FNL Painted Bi-Metal Screws With Bonded Sealing Washer

- Hardened point for self-drilling
- Provides corrosion resistance
- Compatible with treated lumber
- 304 Stainless Steel



Head - Hex Washer Drive - Hex - Unslotted							
	#9						
	Barn Red	Charcoal Gray	Clay	Evergreen	Light Gray	Light Stone	White
Length	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.
1"	11101627	11101632	11101630	11101628	11101631	11101629	11101626
1-1/2"	11101635	11101640	11101638	11101636	11101639	11101637	11101634
2"	-	11101648	11101646	11101644	11101647	11101645	11101642
2-1/2"	11101651	11101656	-	-	-	-	11101650

Bent Anchor Bolts Cont.

Bent Anchor Bolts Supplied without Nut & Washer

ROCK RIVER

Part No.	Diameter	Length	Finish	Material	Head Length	Thread Length	Pkg. Qty.
50052	1-1/4"	12"	Plain	Steel	3"	6"	10
50053	1-1/4"	14"	Plain	Steel	3"	6"	10
50054	1-1/4"	15"	Plain	Steel	3"	6"	10
50056	1-1/4"	18"	Plain	Steel	3"	6"	10
50057	1-1/4"	21"	Plain	Steel	3"	6"	10
50058	1-1/4"	24"	Plain	Steel	3"	6"	10
50059	1-1/4"	30"	Plain	Steel	3"	6"	10

Bent Anchor Bolt Sleeves

Bent Anchor Bolt Sleeves

Anchor bolt sleeves are the cost effective solution to anchor bolt alignment problems.

Part No.	Bolt Diameter	Thread Size	Shell Diameter	Shell Length	Material
50060	1/2"	13	2"	5"	Polyethylene
50061	3/4"	10	2"	5"	Polyethylene
50062	5/8"	11	2"	7"	Polyethylene
50063	3/4"	10	2"	7"	Polyethylene
50064	7/8"	9	2"	7"	Polyethylene
50065	1"	8	3"	10"	Polyethylene
50066	1-1/4"	7	4"	10"	Polyethylene
50067	1-1/2"	6	4"	15"	Polyethylene
50068	1-3/4"	5	4"	15"	Polyethylene
50069	2"	4.5	4"	18"	Polyethylene
50070	2-1/4"	4.5	4"	18"	Polyethylene
50071	2-1/2"	4	6"	24"	Polyethylene
50072	3"	4	6"	24"	Polyethylene
50073	4"	4	6"	24"	Polyethylene
50074	5"	4	6"	24"	Polyethylene

Chemical Anchors

Hammer-In Glass Adhesive Capsules

ROCK RIVER

Features/Advantages

- Pre-measured adhesive
- No expensive dispensing tools
- Sand and aggregate mixture is closest to natural concrete

Part No.	Capsule Size	Length	Type	Hole Diameter	Pkg. Qty.
0140192	1/2"	3-3/4"	Chemical Anchor	9/16"	10
0140193	5/8"	3-3/4"	Chemical Anchor	3/4"	10
0140194	3/4"	4-3/4"	Chemical Anchor	7/8"	10
0140196	1"	8-1/4"	Chemical Anchor	1-1/8"	6

Spin-In Glass Adhesive Capsules

Features/Advantages

- Pre-measured adhesive
- No expensive dispensing tools
- Fast, simple installation
- Self-contained, single point fastening

Part No.	Capsule Size	Length	Type	Hole Diameter	Pkg. Qty.
0140198	1/2"	3-3/4"	Chemical Anchor	9/16"	10
0140199	5/8"	3-3/4"	Chemical Anchor	3/4"	10
0140200	3/4"	4-3/4"	Chemical Anchor	7/8"	10
0140202	1"	8-1/4"	Chemical Anchor	1-1/8"	6

Stud Anchors

Rock River™ Carbon Steel - Chisel Point Zinc Plated After Cutting

ROCK RIVER

Chisel Anchor Studs are used with the Spin-In Type Chemical Capsule Anchors.

Part No.	Diameter	Length	Pkg. Qty.
0123092	1/2"	6-1/4"	10
0123093	5/8"	7-1/2"	5
0123094	3/4"	9-1/2"	5
0123095	7/8"	10-1/4"	5
0123096	1"	11-3/4"	5
0123097	1-1/4"	14"	5

Screw Anchors

ITW Red Head Tapcon® Concrete and Masonry Anchors

RED HEAD Concrete Anchoring Solutions

The Original Masonry Fastening System - now with "Advanced Threadform Technology™". The Original masonry anchor that cuts threads into concrete, brick or hollow block. Advanced thread design makes installation easier with less torque required. Tapcons Anchors® are reversible and removable and they can be installed close to a concrete edge.

Product Features:

- Fast installation...drill a hole....drive an anchor.
- Packaged with one Tapcon® "close tolerance" Carbide tipped masonry drill bit per 100 anchors. Also available in bulk packaging.
- Available in 3/16" diameter up to 4" in length and 1/4" diameter up to 6" in length.
- Compatible for use in ACQ treated wood.
- Replaces small diameter expansion anchors, plugs and screws in light to medium-duty applications.
- Reversible and removable....can be installed close to an edge.
- Made in USA.
- ICC-ES ESR-1671, ESR-2202
- Extended corrosion protection with Blue Climaseal coating.

Applications:

- Electrical junction boxes and conduit clips to masonry.
- Wood headers and furring strips to masonry.
- HVAC strapping to masonry.
- Plywood backer boards to masonry.
- Exterior insulation systems to masonry.

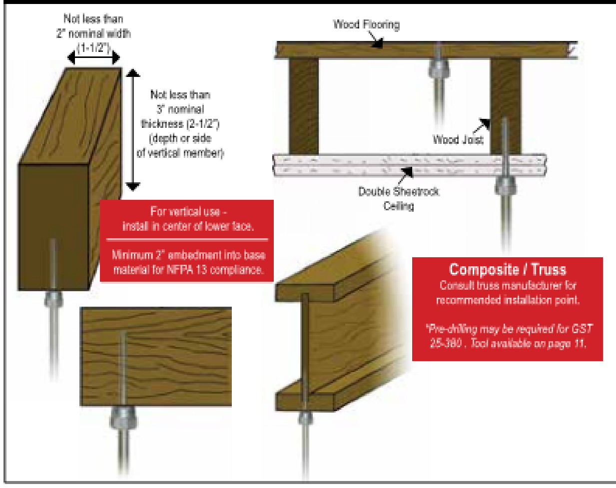
Part No.	Diameter	Length	Material	Drive	Head	Pkg. Qty.	Mfg. No.
51530	3/16"	1-1/4"	Steel	Slotted / Hex	Hex	100	3139407
51531	3/16"	1-3/4"	Steel	Slotted / Hex	Hex	100	3141407
51532	3/16"	2-1/4"	Steel	Slotted / Hex	Hex	100	3143407
51533	3/16"	2-3/4"	Steel	Slotted / Hex	Hex	100	3145407
51534	3/16"	3-1/4"	Steel	Slotted / Hex	Hex	100	3147407
51535	3/16"	3-3/4"	Steel	Slotted / Hex	Hex	100	3149407
51536	3/16"	4"	Steel	Slotted / Hex	Hex	100	3151407
51540	1/4"	1-1/4"	Steel	Slotted / Hex	Hex	100	3153407
51541	1/4"	1-3/4"	Steel	Slotted / Hex	Hex	100	3155407
51542	1/4"	2-1/4"	Steel	Slotted / Hex	Hex	100	3157407
51543	1/4"	2-3/4"	Steel	Slotted / Hex	Hex	100	3159407
51544	1/4"	3-1/4"	Steel	Slotted / Hex	Hex	100	3161407
51545	1/4"	3-3/4"	Steel	Slotted / Hex	Hex	100	3163407
51546	1/4"	4"	Steel	Slotted / Hex	Hex	100	3165407
51547	1/4"	5"	Steel	Slotted / Hex	Hex	100	3167407
51548	1/4"	6"	Steel	Slotted / Hex	Hex	100	3205407
51550	3/16"	1-1/4"	Steel	Phillips	Flat	100	3169407
51551	3/16"	1-3/4"	Steel	Phillips	Flat	100	3171407
51552	3/16"	2-1/4"	Steel	Phillips	Flat	100	3173407
51553	3/16"	2-3/4"	Steel	Phillips	Flat	100	3175407
51554	3/16"	3-1/4"	Steel	Phillips	Flat	100	3177407
51555	3/16"	3-3/4"	Steel	Phillips	Flat	100	3179407
51556	3/16"	4"	Steel	Phillips	Flat	100	3181407
51560	1/4"	1-1/4"	Steel	Phillips	Flat	100	3183407
51561	1/4"	1-3/4"	Steel	Phillips	Flat	100	3185407
51562	1/4"	2-1/4"	Steel	Phillips	Flat	100	3187407
51563	1/4"	2-3/4"	Steel	Phillips	Flat	100	3189407
51564	1/4"	3-1/4"	Steel	Phillips	Flat	100	3191407
51565	1/4"	3-3/4"	Steel	Phillips	Flat	100	3193407
51566	1/4"	4"	Steel	Phillips	Flat	100	3195407
51567	1/4"	5"	Steel	Phillips	Flat	100	3197407
51568	1/4"	6"	Steel	Phillips	Flat	100	3203407

FASTENERS

SAMMYS® FOR WOOD

SAMMYS® FOR WOOD - Vertical Application

Application



Product Features

- No pre-drilling required.
- Quick to install using the Sammy Nut Driver with an 18V cordless drill.
- Saves time from traditional methods.
- Reduces installation costs.
- Assembled in the U.S.A.

View our installation videos! YouTube

Approvals	Rod Size	Part Number	Model	Screw Descriptions	Ultimate Pullout (lbs)	UL Test Load (lbs)	FM Test Load (lbs)	Box Qty	Case Qty
VERTICAL MOUNT									
	1/4"	8002957	GST 100	1/4 x 1"	210 (7/16" OSB) 670 (3/4" Ply)			25	125
	1/4"	8003957	GST 200	1/4 x 2"	1760 (Fir)			25	125
UL	3/8"	8007957	GST 10	1/4 x 1"	210 (7/16" OSB) 670 (3/4" Ply)	300		25	125
UL, FM	3/8"	8008957	GST 20	1/4 x 2"	1760 (Fir)	850	1475	25	125
UL	3/8"	8068925	GST 20-SS	1/4 x 2"	1760 (Fir)	850		25	125
UL	3/8"	8009925	GST 25-380	3/8 x 2-1/2"	2113 (Fir)	1500		25	125
UL, FM	3/8"	8010957	GST 30	1/4 x 3"	2060 (Fir)	1500	1475	25	125
	1/2"	8013925	GST 2	1/4 x 2"	1760 (Fir)			25	125
	1/2"	8015925	GST 3	1/4 x 3"	2275 (Fir)			25	125

#14 Black Nut Driver Part # 8113910

#14 SW Red Nut Driver Part # 8114910

ASSEMBLED U.S.A.

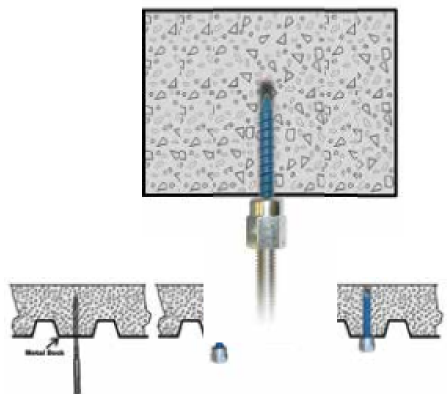
RoHS Compliant

SPECIAL NUT DRIVER SYSTEM: The nut drivers were designed with a unique spin-off feature which provides a fast and safe installation each time. When the face of the driver comes into contact with the material you are installing into, continue drilling until nut driver spins free. Installation is then complete. Warranty requires the use of the appropriate nut driver for installations.

SAMMYS® FOR CONCRETE

SAMMYS® FOR CONCRETE - Vertical Application

Application



Product Features

- Easy two step process (Drill hole & drive Sammys concrete anchor).
- ¼" pre-drilled pilot hole required.
- Concrete Installation Tool available for a one tool installation process.
- Assembled in the U.S.A.

View our installation videos! YouTube

#14 Black Nut Driver Part # 8113910

#14SW Red Nut Driver Part # 8114910

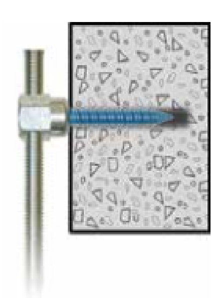
Approvals	Rod Size	Part Number	Model	Screw Descriptions	Ultimate Pullout (lbs)*	FM Test Load (lbs)	Box Qty	Case Qty
VERTICAL MOUNT								
	1/4"	8058957	CST 200	5/16 x 1-3/4"	2400		25	125
FM	3/8"	8059957	CST 20	5/16 x 1-3/4"	2400	1475	25	125
	1/2"	8060925	CST 2	5/16 x 1-3/4"	2400		25	125
FM ICC-ESR 3699+FM	3/8"	8306957	CCST 516	5/16-14 x 2-1/2"	857**		25	125

For complete performance data see ICC Report ESR-3699

* Tested in 3000 PSI concrete ** Pullout strength for Cracked Concrete and Seismic Zones A-F

SIDEWINDER® FOR CONCRETE - Horizontal Application

Application



Product Features

- Easy two step process (Drill hole & drive Sammys concrete anchor).
- ¼" pre-drilled pilot hole required.
- Concrete Installation Tool available for a one tool installation process.
- Assembleded in the U.S.A.

View our installation videos! YouTube

#14SW Red Nut Driver Part # 8114910

Approvals	Rod Size	Part Number	Model	Screw Descriptions	Ultimate Shear (lbs)*	FM Test Load (lbs)	Box Qty	Case Qty
HORIZONTAL MOUNT								
FM	3/8"	8061957	SWC 20	5/16 x 1-3/4"	2450	1475	25	125
FM ICC-ESR 3699+FM	3/8"	8307957	SW-CCST 516	5/16-14 x 2-1/2"	857**		25	125

* Tested in 3000 PSI concrete ** Pullout strength for cracked concrete and Seismic Zones A-F

ASSEMBLED U.S.A

SPECIAL NUT DRIVER SYSTEM: The nut drivers were designed with a unique spin-off feature which provides a fast and safe installation each time. When the face of the driver comes into contact with the material you are installing into, continue drilling until nut driver spins free. Installation is then complete. Warranty requires the use of the appropriate nut driver for installations.

Appendix B – Raw Data Set

Fastener A		
	Concrete	Mass Timber
Test Number	Time to Install	
1	16.86	1.51
2	14.73	1.61
3	14.03	1.35
4	14.56	1.26
5	13.43	0.86
6	12.33	0.95
7	11.28	0.58
8	12.48	1.06
9	12.1	1.03
10	13	1
11	12.41	0.85
12	12.58	0.98
13	11.83	1
14	13.55	0.91
15	11.18	0.9

Fastener B		
	Concrete	Mass Timber
Test Number	Time to Install	
1	11.65	2.55
2	13.98	2.3
3	15.88	2.67
4	11.86	2.3
5	13.01	2.18
6	11.11	2.55
7	11.38	2.71
8	12.8	2.26
9	13.1	1.63
10	12.5	3.86
11	11.35	6.33
12	11.7	2.26
13	10.75	1.25
14	13.13	2.16
15	12.15	1.23