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INDUSTRIAL BRIDGE CONSTRUCTION: NEED FOR A MORE EFFECTIVE BRIDGE CONSTRUCTION PROCESS

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Designing for ease of construction is something that is always demanded by contractors and a challenge for the designers. It is widely known that the ability to influence a structure and its future properties is at its greatest in early stages, i.e. the project preparation phase followed by the design phase. Despite the fact that there is an obvious need for knowledge of construction in design work, there is a lack of a consistent and structured transmission of experience between the construction stage and the designing engineers. The results in this project are achieved based upon three standalone studies. A thorough literature review, a meta-analysis of the current research covering effective bridge construction and a study of the current industrial view on how the industry intend to achieve a more effective bridge building process. Based upon these studies it is clear that using a holistic approach and a production oriented design methodology is likely to generate the progress that the construction industry needs.

Keywords: Sustainable, Efficient process, Structural design, Knowledge transfer, Integrated design process.

1 INTRODUCTION

Previous research has tried to introduce the concepts of industrial construction without succeeding. Only in Sweden there have been several attempts to unify around one definition and its content, in both housing and infrastructure (Harryson 2002, Löfgren 2002, Lessing 2006, Harryson 2008). Nevertheless, no significant change has occurred within the industry up to date and the concept of industrial construction seems to still be a product of academia.

The rate of productivity and innovation capacity within the building industry of today is perceived to lead to a poor return of investment within infrastructures. One of the identified reasons for the poor investments are mainly due to the non-integrated design and production process, and the long lead-time in both planning and execution of a construction project. In addition to less value for invested money, the ineffectiveness causes disturbance for stakeholders in society (SOU 2012, Statskontoret 2010).

One of the key issues in today’s research is the integration of design and construction, so when reviewing the literature it can be a bit surprising that we still are facing the problems that we are today. As early as 1964, the Banwell-report stated that "design and construction must be considered together and that in the traditional contracting situation, the contractor is too far removed from the design stage at which his specialized knowledge and techniques could be put to invaluable use" (Griffith and Sidwell 1997). In the US, the term of constructability was stated by the CII Task Force as "the optimum integration of construction knowledge and experience in planning, engineering, procurement, and field operations to achieve overall project objectives". A similar term, buildability, is defined in the UK by CIRIA in 1983 as "the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building"(CIRIA 1983). They both try to describe the importance to have a comprehensive view and not overlook project activities (Fischer and Tatum 1997). Throughout the years, a vast number of studies have been done concerning the two terms, but in general buildability concerns to what extent the designer may influence the 'ease of construction' on site, while constructability includes management issues and should describe, the optimum use of overall construction knowledge' (CII 1986), (Griffith and Sidwell 1997, Simonsson 2011). Studies of buildability or constructability have also indicated that there is different focuses of interest within different countries (Lam *et al.* 2006).

2 SCIENTIFIC APPROACH

This article aims to highlight the importance of using a systematic and holistic approach to achieve productivity improvements within the construction industry. Despite the "proven" benefits by considering buildability and constructability issues in design and the use of industrial processes, there has been a strong inertia to get the industry to adopt these approaches to the fullest. This is a descriptive review paper that draws on existing research and by observation of previous studies intends to describe the multifaceted problem of generating a more effective bridge construction process.

3 EFFECTIVE BRIDGE CONSTRUCTION

Why introduce constructability or buildability in construction of bridges? The answer to that question can appear somewhat obvious, but the fact remains that the productivity in the construction industry is lagging behind other industries. This is indicated by several reports, both in Sweden and other countries, (SOU 2002, SOU 2012), and this is also evidenced by the increasing costs and lead time in construction. The design and the conduct of a construction are closely attached and highly dependent to each other. Usually, the choice of construction method dictates the rules of the design. Due to the sequential design process, a construction method often needs to be assumed in design without necessarily considering all its requirements (Fischer and Tatum 1997). Also as a result of the sequential flow of design and construction, comments by construction workers regarding the inadequate and inconsiderate designs are there for not uncommon (Lam *et al.* 2006). There is also a historical aspect to this. This has been a matter of concern ever since the design and construction functions once were separated from each other and becoming two professions with divergent goals (Puddicombe 1997). This separation and divergent goals have led to decreased will to co-operations leading to time, cost and quality becoming areas of disagreement. There is a complicated relationship of constructability with regard to time, cost and quality performance. A relationship which is also often neglected by construction clients in the early stages of a construction project. To prevent this and to minimize surprises and concerns in the tendering phase, (Lam *et al.* 2007) makes an effort to quantify constructability into something understandable by the project stakeholders. If so, it also can be assessed and improved where necessary. (Tatum 1987) however, indicates that the benefits of constructability can be hard to quantify, but at the same time that it is important to remember that there can be other beneficial aspects than time and money. Team building, improved coordination of design and construction, greater construction planning, and adoption of a project viewpoint by all team members are some aspects which can be beneficial through constructability.

3.1 Responsibilities

What are then the driving forces to introducing constructability aspects? One main reason supporting introduction of buildability and constructability concepts within the construction industry is the reduction of waste. In a Swedish survey (Josephson and Saukkoriipi 2005), the cost related to non-value activities was shown to be as high as 30 % which is one single reason alone to make a change. Of course, there is always uncertainties in the definition of waste itself, but it is still alarmingly high numbers. This reason seems clearly not to be sufficient, even though it might should be.

A market driven innovation is lacking because of deficient incentives, insufficient competiveness and because demands of quality and function are not clearly formulated. In Sweden this is mainly related to its market for infrastructure. The main client within Swedish infrastructure is the Swedish Transport Administration (STA), which thereby has a unique position to influences the productivity and innovation capacity of the building industry (Harryson 2008). Productivity is obviously and closely related to innovation, constructability and buildability and several other aspects which are connected to industrial construction. In the same manner as industrial construction, productivity is also a multifaceted concept and there is no consensus or one generally accepted definition of the term as such (Tangen 2005). This is related to the fact that productivity is dependent on the context that it is measured within. Without knowing the context, or even background and profession, there is a large risk of interpreting the outcome incorrectly. One clear concern with the idea of productivity is, though it acts as one of the most important measures to evaluate an organizational success, that there is no consensus in interpreting it (Polesie 2011). In research there has been many efforts made to create a scheme over the different relationships related to the term and to define it c.f. (Tangen 2005, Polesie 2011).

3.2 Industrial Bridge Construction

Research within the field of industrial construction is nothing new. The biggest challenge the industry is facing is probably how to implement the results from the industry. Within the house building industry, the implementation of industrial processes has reached the farthest, even though it has not propagated to any important change as a future method in the construction industry (Malmgren 2014).

Based on the TFV-concept (Transformation – Flow – Value) presented by (Koskela 2000) which is one comprehensive theory for the construction industry, Harryson (2008) presented three cornerstones of industrial bridge construction which were identified as process development, productivity development and product development, i.e. the three P's. Serving as the natural link and generating a continuous circle of development between the three P's is information and communication technologies (ICT). The rapid progress of development and increased knowledge about the use and strategies about how to implement the use of ICT and Building Information Modeling (BIM) into industrial construction, this might be the single most important factor for developing new and successful industrial concepts (Harryson 2008).

Productivity and innovations are clearly related. New and developed methods, processes, and products is a constant need for the construction industry to be competitive. This need will never reach a final state, and instead a continuous development of the building market is needed. A development that should incorporate the advancements of other areas such as materials science and technology, design and analysis methods, production techniques, as well as the rapid development in ICT (Olofsson *et al.* 2010).

3.3 Learning Organizations

A prerequisite to introduce industrial methods in the construction industry is to have systems to manage experience feedback, and thereby creating a learning organization. It is clear, in these days more and more industries have embraced the trend of using integrated design and integrated teams (D Forgues and Koskela 2008, Sumner *et al.* 1999), so also within the construction industry. Stated by Radtke and Jeffrey (1993), one success factor to introduce constructability is to develop integrated teams consisting of personnel from owner, design-engineering and contractor organizations. Commonly found in the literature, e.g. (Radtke and Jeffrey 1993), a prerequisite for these teams to be successful, getting the right people to these teams are critical. Interestingly, while research promote working in teams, the same research have found few examples of effective team collaborations. Examples of dysfunctional teams are on the other hand plenty, (Sumner *et al.* 1999). Often, it is not possible to freely choose team members within the projects. The teams will consist of, at the time, available resources.

In design firms, which can be seen as a knowledge enterprise, stored knowledge usually are available in reference documents from completed projects, or in the form of knowledge at the individual level. With inadequate management of information along with staff turnover there is a high risk of losing valuable knowledge if this is not handled properly. Johansson (2012) refers to (Polanyi 1983) by a citation "we know more than we can tell". This indicates that when knowledge is stored on an individual level, an organizations level of knowledge may very well exceed what it explicitly can express. This clearly gives an indication that it is necessary to find a systematic way to carefully nurture the knowledge gained within a team or organization by creating a learning environment. Sumner *et al.* (1999) states that "Integrating working and learning is not a desirable luxury – it is a fundamental requirement for businesses to remain competitive". Problems with integrated teams have also been highlighted in research by Forgues and Koskela (2008), which indicates that team efficiency is more governed by socio-cognitive aspects then technological.

4 CONCLUSION

Introducing buildability or constructability concept into construction is generally, among many, a reason for reducing construction time, construction cost, as well increased quality and safety. Many aspects within constructability and buildability have common features as within industrial construction. By this common ground, it is also plausible to utilize industrial processes within bridge construction to achieve a construction project set goals. To reach the desired output, often measured in customer value, it is a necessity to early clarify these values, continuously monitor and follow up possible changes.

If an effective and sustainable bridge building process was clearly defined, a design process that combines aspects of structural resistance and production can be developed and integrated into the building process. This new design process should include the above mentioned advancements and consider already established innovations.

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