CONSTRUCTOR LED CONSTRUCTION HAZARD PREVENTION THROUGH DESIGN (CHPTD)

Thomas Mills, Department of Building Construction, Virginia Polytechnic Institute and State University

ABSTRACT

It is the contention of the author that preventing or reducing safety and health hazards in the U.S. construction industry by increasing the use of hazard prevention through design can most advantageously be pursued by approaching it within the Design Build/Design Manage project delivery system. This is supported by noting that close to one-half of the $400B annual U.S. non-residential construction is being delivered using a constructor-led design build delivery strategy and that 75% of the residential single family homes in the US are builder/vendor sales. One can also observe that in commercial that design-build is maturing into other delivery strategies including design-manage, design-assist, and integrated project delivery through teamed stakeholders. Owners are providing the lead in outsourcing expertise to construction professionals to manage not only the construction process but the design process as well. Hence as construction professionals assume a stronger leadership role in the overall delivery process, aspects of construction hazard prevention through design become more pronounced and under their lead.

This position paper addresses the current and advancing state of construction hazards prevention through design-for-safety in alternative delivery strategies and proposes a constructor led strategy. The reasons why a constructor-led strategy has the greatest impact, chance of success, advantages and barriers and proposes a 10 point strategy aimed toward implementation.

Keywords: Design for Safety, Design-build, Construction safety, Hazard prevention

INTRODUCTION

This position paper presents an alternative view to the traditional architect/engineer Construction Hazard Prevention through Design (CHPtD) focus that many Design for Safety (DfS) researchers are pursuing. The alternative is presented in an effort to consolidate the previous research and to propose that a more productive strategy in U.S. implementation is through a constructor-led implementation initiative. Derived from this investigation are 10 discussion points aimed at supporting construction practitioner implementation. The concept of constructor-led design-for-safety in the U.S. is supported by noting that close to one-half of the $400B annual U.S. non-residential construction is being delivered using a constructor led design build (DB) delivery strategy (DBIA, 2009) and that 75% of the residential single family homes in the US are builder/vendor sales (U.S. Census Bureau, 2009). One can also observe that commercial design-build is maturing into other delivery strategies including design-manage (DM), design-assist (DA), and integrated project delivery (IPD) through teamed stakeholders.

This paper in its support of constructor-led hazard prevention through design is presented in four distinct parts, Part 1 is a critical focus through the literature on the current design-for-safety thinking, Part 2 identifies from the literature the inherent weaknesses and barriers to implementing a traditional design-for-safety focus, Part 3 explores the viability of the alternative constructor-led design-for-safety, and Part 4 develops the focus for an implementation strategy.

Several recent studies state that, by altering the design, injurious construction accident or incident occurrences could be reduced by anywhere between 22% and 60% (as cited by Gambatese et al., 2008, Creaser, 2008). Although one may take exception to the inclusion of specific incidences there is no question that by approaching defined pieces of work with a design for safety mindset that a reduction in the opportunities for injurious health and safety incidents can be influenced. In no way should this mindset be equated to leading the design for safety process. It is also evident from the literature that construction worker initiated design for safety considerations have greater impact and are more likely to be implemented (Weinstein et al., 2005). Reinforcing the idea of a constructor led strategy can be deduced by the accident causation conclusions that constructor's drew with regard to the root cause of an accident or fatality in at least one of these studies (Gambatese et al., 2005). Thus there is evidently some divergence of opinions, particularly from the constructor viewpoint, on the impact that design has on the root causes of a construction accident. From the literature it is evident that construction site safety is the domain of the constructor and should continue to remain such. This insight supports constructor led implementation through awareness, timing, and workplan development. Few constructors would welcome designers to develop a strategy to improve site safety. The reasons are obvious and plainly stated in the literature. Of concern to this author is the growing effort to force inexperienced and less than knowledgeable design engineers into the role of construction site safety professionals (Gambatese et al., 2005, Toole, 2005, Toole and Gambatese, 2008). If designers wish to pursue this role then the author believes they should assume the risk and liabilities associated with their actions and solicit their errors and omissions insurance carriers to broaden their coverage for this practice.

PART 1 – TRADITIONAL DESIGN FOR SAFETY THINKING

Reflecting upon the early work of Hinze and Wiegard (1992) and assessing the current work of Toole and Gambatese (2008) one recognizes that the design-for-safety intent is to 'seek a means for sensitizing designers … to the need of providing for construction worker safety'. This same philosophy can be applied to the constructor as well. Since 1992 design-for-safety has been a progressive movement that has continued to expound upon a variety of common and recurring obstacles to implementing hazard prevention through design, namely lack of designer construction and worker safety experience, designer liability, and separation of contractual domains. Clearly what design and designers focused upon is product design, while construction is a team-based process utilizing creative means and methods to safely and profitably produce the designed product. That does not mean that product design cannot incorporate safety features, in fact that is the baseline origin of the design-for-safety philosophy that in the U.S. was first prompted by Ralph Nader's book Unsafe at Any Speed (1965) and followed through by the auto industry (GMC, 1965) and then expanded into highway design and construction (Schoppert, 1965).

The strategic thinking to incorporate design for safety through consulting designers has remained relatively consistent since first broached by Hinze and Weinstein (1992) and continues today as evidenced by the recent design-for-safety specific issue of the Journal of Safety Research (Howard, 2008). Among the leading U.S. design-for-safety researchers the focus remains solidly in the design domain and appears to undervalue the constructor. Although the author believes that constructor involvement is inadequately focused, these same researchers appear to support a greater opportunity for success through builder/constructor leadership. What is lacking is a body of literature that directs the strategy toward constructors.

There are two major thrust areas now being focused in the design for safety domain that stresses an even stronger designer led incursion into a traditional constructor led arena, one of which may be detrimental to actualizing and harmful to workers. These two thrust areas are 1) modeling hazard prevention through design implementation by emulating the Leadership in Energy and Environmental Design (LEED) certification model, and 2) using Building Information Modeling (BIM) to assist in improving the product design for worker safety.

The loosely defined, but implied implementation strategy that mimics LEED rating & certification focuses on establishing a design engineering certification that may eventuate into several realities, 1) certified design-for-safety professionals, that in all probability would have little actual construction experience or knowledge, but would secure certification, and 2) a checklist approach used by these certified professionals to address hazards. Although this is an admirable goal the author believes it will have little impact on improving construction site safety. On the contrary it may create a false sense of on-site safety with the unintended result of poorly addressed hazard identification. Currently those construction companies with good to great safety records achieve their records by incorporating safety professionals, are using diverse safety tools including checklists, zero accident techniques, hazard specific training, work plans that incorporate safety planning, and the use of qualified subs that follow similar procedures. Companies that have poor safety records, e.g., residential and small construction companies, will continue to approach safety in an unsafe business as usual approach. No form of non-market driven design-for-safety certification will improve these companies safety performance. Instilling a simple but complete implementation strategy that constructor's can adapt to their own processes offers another avenue for delivering a design for safety culture that can own the process.

The strategy of using Building Information Modeling (BIM) as an aid to addressing designed for safety features offers an excellent research area but has its drawbacks. BIM is still in its infancy and is predominantly focused by the building design profession for visualization of the designed product and by the constructor for clash/interference detection and checking. Another consideration for 'smart' models, those capable of adding intelligence, is that they are poorly managed for purposes other than parametric design, geometric control, and the production of 2D drawings for field use. This leaves design for safety out in the cold. Additionally, it is apparent that the industry standard BIM products are focused on product design with very few construction plant objects such as scaffold, shoring, sheeting, anchorage points, nets, hoisting equipment, opening protections, etc. available. These objects are needed elements to incorporate the construction process into a predominantly object (product) focused software. Once an objects library exists construction and design can consider how to integrate these tools into workplans that utilize designed safety features.

PART 2 – BARRIERS TO EXPANDING THE TRADITIONAL CONSTRUCTION DESIGN-FOR-SAFETY THINKING

This section will only focus on two barriers that seem fundamental to constraining the current strategy of designer-led construction hazard prevention through design. These are fundamental in characterizing the nature of the design and construction disciplines. The first consideration is the argument of product versus process design, and the second is the question of controlling means and methods. By recognizing these barriers one can apply their inherent natures in support of constructor implementation.

Product design versus process design

Before one is able to design for safe construction one must understand construction's essence. As both architect and construction manager the author believes he speaks with authority. Design is different from construction. Many designers, including architects and facility design engineers focus in the domains of functionality, performance, and end user requirements. This product design focus envisions permanency of the product and differs tremendously from the temporary nature that is the essence of construction. Construction is an engaged process that features a dynamic and temporary plant. Illingworth's provides the most insightful and perceptive description of construction when he notes that in any form of construction there are only two fundamental activities, 1) the handling of materials and equipment, and 2) by a skill workforce positioning those materials to produce the whole (Illingworth, 2000). This premise quickly separates out the difference between product and process design. This leads the author to the conclusion that construction safety is by nature the domain of construction professionals not design professionals. This doesn't mean that designers should avoid any sensitivity to construction worker safety. They should be sensitive but in a supporting capacity. They cannot and should not be considered as lead construction safety professionals. Toole (2005, 2007) recognizes this condition and has proposed that the engineering profession can offer support by being safety auditors or better yet by providing design for safety strategies and solutions, particularly as members of construction teams. This author also believes that the latter presents the better opportunity to enhance a constructor led approach but also believes that by promoting designers in the role of design for safety certified professionals and field safety auditors can be at risk of creating additional layers of burdensome oversight by professionals that lack the requisite knowledge and skills to be effective. One final consideration in the product versus process discussion is that safe solution sets in a design led approach will naturally coincide (by discipline) with physical product definitions e.g., checklists, etc. will be oriented toward physical components (e.g., roofs) and not worksite hazard classifications (e.g., fall to lower level). Tools that link workplan hazard identifications and not product definitions have a stronger capacity to facilitate hazard reduction.

Control of construction means and methods

By contract, historical precedent, and commonly accepted industry practices the control of construction means and methods remains the domain of the constructor. The author believes this will and should remain the case. In addition to the question of liability (Behm, 2008), the more fundamental question is one of practicality, efficiency, and safety. To shift the responsibility of means and methods undercuts the fundamental ability of the constructor to develop creative and effective means and methods (defined by workplans) that advance the profession and also provide a competitive edge in safe and productive work. Support for the means and methods of construction remaining with the constructor are evident throughout the literature (Coble and Blatter, 1999, Gambatese et al., 2008, Toole, 2005). The literature has many examples of instances that design induced considerations are beneficial to reducing on-site hazards, among these are inadvertently or poorly designed masonry walls, heavy object designs, and deep trenches (Behm, 2005, Gambatese et al., 2005). Means and methods will remain the domain of the construction professional and as such the constructor is in the position to implement design-for-safety during the development of work flow and subsequent work plans. Additionally the decision to implement a specific means and methods strategy on the same project will vary from constructor to constructor and is therefore impractical if not impossible for a designer to accurately determine the appropriate strategy. Therefore, the integration of design for safety concepts into constructor produced workplans tied to a field logging and feedback system are valid implementation components.

PART 3 – VIABILITY OF CONSTRUCTOR LED HAZARD PREVENTION THROUGH DESIGN

One only needs to review the literature to validate the future of implementing an effective design for safety strategy lies with constructor leadership. Weinstein, et.al., (2005) clearly identifies the strength that exists when emanating from the constructor. They identify that among other considerations the likelihood of a proposed design change being implemented is significantly higher 79% versus 20% if recommended by trades' contractors. Additionally, they report that trade contractors have the knowledge to 'pinpoint significant design impacts' that may be overlooked by design professionals while designers are unable to adequately address ergonomic hazard prevention. The decision on hoisting methods are contractor driven and to mandate otherwise would be burdensome and in instances where incorrectly specified could result in worker injury. Construction safety leadership is best left to the people that profitably practice construction. In fact consideration should be given to limiting the design to meeting a standard of care in providing specifications and drawings that establish standards for performance and meet code requirements, set geometric control, and size equipment based on engineered calculations. Greater emphasis by designers in the construction process leads into the abyss of control and supervision a risk that that U.S. designers traditionally avoiding by contract language. On the contrary the constructor traditionally assumes the risk of job site safety hazards and avoiding job site injuries and fatalities is in the constructor's best interest. The above has a direct impact on project profitability and identifying best practices for integration into future design for safety solutions.

One of the early premises of this paper is that design-build, design-manage, and design-assist projects offer better opportunities to influence and incorporate design for safety strategies into project design and procurement. In order to realize this opportunity the task becomes one of implementing a research to practice (R2P) focus that translates academic research on design for safety to the construction field. Notwithstanding the results of the NIST (2002) study that there is no significant difference in design-bid-build or design-build in safety performance, the author believes that a constructor-led focus is a more viable implementation strategy for moving safety forward than preparing designers to implement. The NIST study concluded that on-site safety results from the fact that construction safety must address a variety of strategies regardless of the delivery method in order to ensure a safe work site. Much of this is due to the fact that constructor's develop a broad project safety plan that addresses creating a safe worksite for workers, while using subcontractors, working with different design consultant's documents, yet to be determined means and methods, evolving temporary plant issues, and a variety of differing work packages. Thus designing for safety from the design professional position can only be advisory in nature and of limited scope. To truly affect a design for safety change the concepts must originate from and be 'owned' by the construction team. Both Coble (1999) and Toole (2007) have expressed insight into the strength of constructor led design for safety through design-build projects. Toole particularly addresses the concept of hazard mitigation, using five criteria focused on decision making, within a design-build environment and solely as a design consultant, and concludes that in all the applied instances that an engineer linked to the design-build environment would proactively address the hazard when otherwise they may not. As a result of the inherent nature of these considerations a constructor led strategy involves issues of profitability and risk mitigation, feedback loops, the acceptance of workplan responsibilities, and timeliness of implementation.

PART 4 – STEPS TOWARD IMPLEMENTING A CONSTRUCTOR-LED HAZARD PREVENTION DESIGN-FOR-SAFETY STRATEGY

Previous research consistently indicates that effective design-for-safety is most likely to be addressed when initiated early in the project (Hinze and Wiegand, 1992, Weinstein et al., 2005). This insight quickly nullifies traditional design-bid-build and reinforces design-build and integrated project delivery as the preferred method to achieve design-for-safety implementation. Thus one of the keys to implementation is timely initiation of the process with construction expertise at the table. In a most design-build projects the constructor takes the lead and thus is managing design consultants that are on the same team and frequently share in the same profits. Many times these design consultants are also major subcontractors, e.g., mechanical, electrical, plumbing, heating, ventilations, concrete and thus not only supply design but supply a workforce. They originate both product and process. This allows awareness, timely decision making, in-house work plan origination, acceptance of the concepts, mutually allocated risk sharing for maximizing profitability, monitoring and feedback among design and construction.

Based on previous research reasonable insights into the considerations that make design-for-safety a value added consideration for designers has been adapted to constructors. A consolidated 10 point strategy to implement constructor-led hazard prevention through design has been derived by the author from a review of the literature and re-interpreted to apply to a constructor. These 10 points are stratified and include a feedback loop to address continuous improvement in the design-for-safety process with the intent of growing a design for construction safety culture. The intent is that the considerations identified in Table 1 are conducive to implementing a constructor led design-for-safety strategy and can be used to begin discussion on an alternative and parallel course with the contemporary approaches being directed toward a designer-led design-for-safety culture. The author believes the proposed 10 point strategy is particularly applicable to projects that are approached from a design-build, design-manage, design-assist, and integrated project delivery perspective and can be adapted to residential builder/vendors as well.

1	Awareness	Awareness is critical to address maximum inclusion of all the participants and secure buy-in of the design-for-safety process and its benefits. Awareness becomes pervasive to the team and should concentrate in two major areas: 1) Awareness of the importance of the entire participant supply chain working collectively to improve worker safety. 2) Identification of the strengths each delivery method brings to improving on-site worker safety through early product and process design involvement.
2	Timing	Timing has a direct impact on design-for-safety implementation (Weinstein et al., 2005). Placing this in the forefront allows maximum inputs from all the participants and leads to downstream risk mitigation.
3	Acceptance	Acceptance is an affirmation that liability exists for all parties and that by collectively accepting the risk individual liability is reduced and a concentration on proposing and implementing safe work solutions can be implemented.
4	Profitability	A business case can be made for profitability as a driver that extends to all parties. This can be evidenced by a reduction of worker compensation claims, a

		reduction in lost time incidences, increased productivity, reduced insurance premiums, less errors, and less rework.
5	Agenda	It is essential that design-for-safety be placed on all agendas, including constructability review, procurement, operations, commissioning, and closeout. By formal agenda placement design-for-safety becomes institutionalized and creates a culture of addressing worker safety at all levels. Potential hazards are identified, resolved, or passed forward in a Hazard Identification Folder that stays with the project similar to commissioning documentation.
6	Tools	Tools are organizational design-for-safety capital assets; they are acquirable and can take the form of checklists, design manuals, best practices databases, graphics, and BIM. Standing considerations in constructability and procurement reviews will use these tools and lead to a Best Practices Tool for evolving worker safety considerations when developing workplans.
7	Workplans	This is unconditionally the domain of the construction work designer as they develop the workplan, Job Hazard Analysis (JHA) and rolls a design job hazard analysis (DJHA) into the workplan. Best practices are draw from the Best Practices Folder allowing design-for-safety to be incorporated further downstream into Project Operations. Although not limited to construction, Liberty Mutual Insurance indicates that over 74% of the most debilitating work place injuries result from three originators; 1) overexertion, 2) slips and falls, and 3) struck by/against (Braun, 2008). Simply considering these three hazards construction workplans can be developed that address process and product design improvements that mitigate or eliminate the risks associated with these specific hazards.
8	Logging	Incorporate design-for-safety within incident logging. Establish and use an identification metric that allows tracking incidents to hazards to design features.
9	Integration	Integrate design-for-safety with an organizations quality management system which if frequently based on best practices, feedback loops, and continuous improvement.
10	Feedback	Establish a formal mechanism to feedback lessons learned and instill Best Practices into design-for-safety implementation.

Table 1: Constructor-led design-for-safety implementation points.

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