Construction Site Safety Roles

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Abstract: A survey of design engineers, general contractors, and subcontractors indicates there is not uniform agreement on the site safety responsibilities that should be assumed by each of these groups. Possible explanations for this lack of shared expectations regarding site safety roles are discussed. It is suggested that specific site safety responsibilities be assigned on future projects based on each group's ability to control the factors needed to prevent eight root causes of construction accidents.

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Introduction

Although the Occupational Safety and Health Act was passed 30 years ago, the respective roles of the various parties involved in construction projects for site safety are far from settled. This is particularly true for architects and engineers (A/Es), i.e., design professionals. One of the salient texts on construction site safety (Levitt and Samelson 1987) does not even mention the role of the A/Es. Yet in recent years, industry professionals have been following several high-profile lawsuits and Occupational Safety and Health Administration (OSHA) rulings in which A/Es have been held responsible for accidents suffered on the job site by construction workers (Lunch 1995, 1997; Smith 1998; ''Court'' 1999; Korman et al. 1999; Loulakis and Santiago 2000). Recent attempts to modify the American Society of Civil Engineers (ASCE) Policy Statement 350 on construction site safety indicate there is not agreement within ASCE on the members' site safety responsibilities (Toole and Gambatese 2002).

The objective of this paper is to help clarify the roles of design and construction professionals in site safety. The paper first presents the results of a survey on site safety expectations that indicate that A/Es, general contractors (GCs), and subcontractors are not uniformly agreed on which group should have primary responsibility for site safety. Next, reasons why there are not common expectations about site safety responsibilities are theorized. A causal model about construction accidents is then proposed, and factors associated with each cause are identified. Finally, the respective abilities of the entities typically involved with construction projects to influence these factors are analyzed. This analysis can be used to establish fair and practical expectations on site safety roles based on the assumption that entities that have limited abilities to prevent construction accidents should also have limited responsibility for site safety.

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Empirical Investigation

To investigate whether there is a common understanding of site safety responsibilities among A/Es, GCs, and subcontractors, a telephone and written survey was taken of a sample of firms located throughout Pennsylvania in March and April of 2000. Firms were randomly selected from the yellow pages for the metropolitan areas of Harrisburg, Philadelphia, and Pittsburgh; design engineers were randomly selected from the central Pennsylvania ASCE directory of members. Firms were contacted by telephone and asked if the employee or manager most knowledgeable about safety management within the firm would participate in a brief, confidential survey. Most respondents participated through a 16-question telephone questionnaire. A small portion of respondents preferred to complete the questionnaire in writing via facsimile machine. The participation rates were approximately 30% for GCs and subcontractors, and over 50% for designers. A total of 105 firms participated in the survey, including 54 civil engineering design firms, 26 GCs, and 25 subcontractors. Of the 54 firms that offered civil engineering design services, 32% of these firms also reported that they offered construction management services and 8% reported that they at least occasionally participated in design/build projects.

As part of the survey, participants were asked which entity (owner, A/E, general contractor or subcontractor) should have primary responsibility for each of five areas considered by the writer to be critical to site safety—determining safe means and methods, setting a safe pace of construction, determining what safety equipment will be used, and monitoring for unsafe conditions and for unsafe acts. The results are summarized in Table 1. Participants were also asked which group actually had primary responsibility for each of these five areas related to site safety. The percentages reported were not substantially different.

As shown by the percentages in the *row* labeled GCs, the highest percentage of respondents in all three groups ascribed primary responsibility for site safety to GCs. Few respondents ascribed primary responsibility to A/Es or owners. Interestingly, both A/Es and subcontractors had substantially higher percentages of respondents who attributed primary safety responsibility to their own group. That is, the percentage of A/Es who believe that A/Es should have primary responsibility for site safety is higher than the percentages of GCs and subcontractors who believe that A/Es should have primary responsibility.

The data indicate there are mixed opinions on site safety responsibilities within the entire sample and within each group.

Table 1. Percentages of Respondents Who Stated that Specified Group Should Have Primary Responsibility for Site Safety

Group that should have primary responsibility for site safety	Group surveyed		
	A/Es	GCs	Subcontractors
Owners	3	8	2
A/Es	18	11	5
GCs	67	65	66
Subcontractors	12	17	28

After discussing possible explanations for these mixed opinions, this paper attempts to clarify the respective roles each group should assume by analyzing how much each entity can control the factors that lead to construction accidents. This analysis can then be used to establish fair and practical expectations on site safety roles based on the assumption that entities that have limited abilities to prevent construction accidents should also have limited responsibility for site safety.

Causes of Uncertainty about Safety Roles

This section of the paper discusses four factors that may explain why there is not widespread agreement about the respective roles that the entities typically involved in construction projects should play regarding site safety. The first factor is that detailed expectations about safety roles are not written in project contracts, governmental standards, or anywhere else. The only portion of project contracts that typically even mentions site safety is the general conditions, which are usually one of the model sets of general conditions provided by the American Institute of Architects (AIA) or the Engineers Joint Contract Documents Committee. Both of these documents explicitly state that the responsibility for site safety rests with the general contractor and do not mention the roles, however small, that designers and owners, or subcontractors could or should assume regarding safety (Toole 2002).

One might expect that the construction standards promulgated by the applicable occupational safety and health agency (i.e., federal or state) would specify site safety roles, but this is far from the case. Nearly all construction projects not located in states that have their own OSHA are governed primarily by Title 29, Part 1926, Subparts C–Z of the Code of Federal Regulations (29 CFR 1926). All construction activities are also governed by general industry safety requirements (Part 1910) insofar as they are not superseded by Part 1926 (Toole and Gambatese 2002). In addition, federally funded construction projects are also governed by Subparts A and B of 29 CFR 1926 (California and Michigan have OSHA standards that substantially differ from those promulgated by the federal government's Department of Labor; other states have standards that represent only minor deviations from the federal OSHA standards).

The standard does not clearly establish the safety responsibilities of an owner, A/E, or GC for the safety of a subcontractor's employees. Indeed, except for a small portion of Subpart B (which applies only to federally funded projects) and one sentence in 1926.20, nowhere in 29 CFR 1926 are the terms owner, general contractor, and subcontractor even used. Instead, all references are to the duties of *employers* of employees potentially exposed to hazards. Thus, the only nationally required construction safety standards establish proactive safety management responsibilities for entities involved in a construction project only to the extent that they have employees on-site who may be exposed to hazards.

A second explanation for why there is not a common understanding of safety roles is the apparent conflict between the OSHA text and the behavior of OSHA the agency. Despite the focus on an employer's safety duties in the text, the agency does occasionally cite entities other than employers for violations associated with construction workers. OSHA does this based on the Multi-Employer Policy that is included in OSHA's internal *Field inspection resources manual*. The policy states that entities other than an exposed employee's employer can be cited if they created the hazard, were tasked with correcting the hazard, or controlled the construction operations. A recent article documented that a substantial increase in the number of OSHA citations of A/Es has occurred since the early 1980s (Korman et al. 1999).

Recent salient court decisions may be a third reason for uncertainty about safety roles. Contractual clauses assigning safety roles on projects have meant little in court. Several decisions have not only held designers and construction managers (CMs) partially responsible for overseeing site safety, but also communicated a fundamental misunderstanding about the roles these entities typically play on construction sites. Although the final rulings on the Simpson, Gumbertz & Hager and the CH2M Hill cases were ultimately in favor of the A/Es, (Smith 1998; ''Court'' 1999; Korman et al. 1999), the number of appeals necessary to get to this point was frightening to those following the cases.

The fourth factor contributing to uncertainty about safety roles has been the recent literature arguing for increasing design professionals' safety obligations. Several construction researchers have published a stream of articles that argue that designers should proactively consider site safety during the design stage (Hinze and Wiegand 1992; Gambatese et al. 1997; Gambatese 1998, 2000). These researchers have identified ways that A/Es can influence site safety during construction by making better decisions during the design stage. These researchers have done a service to the industry by articulating two fundamental points that are discussed only briefly in ASCE's current (2001) Policy Statement 350. First, for moral reasons (and perhaps practical risk management reasons), construction safety should be the concern of all individuals and organizations involved in construction projects. Second, it is important that all parties involved in specific projects communicate expectations regarding site safety roles throughout the project.

While not denying the specific contributions this literature has made, it is the opinion of the writer that this stream of literature has increased the uncertainty among the design, construction, and regulatory communities. Although the articles address the role of A/Es in safety *during design*, it is a natural extension to infer that A/Es should play a role in safety *during construction*. Furthermore, it should be pointed out that to increase A/Es' sensitivity to site safety, these researchers advocate dramatic and costly shifts in the training, design process, and attitude of designer professionals. Before pursuing these shifts, it seems it would be prudent to first increase our understanding of the extent to which design professionals can influence site safety. Ultimately, the investigation into this issue should be empirical. In the meantime, a theoretical framework for assigning safety roles is needed.

Causality of Accidents

Having suggested that current understanding of site safety roles is a problem within the construction industry, this paper now at-

Table 2. Root Causes of Construction Accidents

Root cause	Description	Example
Lack of proper training	An employee was not properly trained in recognizing and avoiding job hazards.	A new employee is sent up to work on a sloped roof without being trained on the proper use of the fall restraint system and ties off to a deficient anchor.
Deficient enforcement of safety	An employee's supervisor (or other individual with safety oversight responsibilities) knew that prescribed methods for avoiding hazards were not being followed, but neglected to enforce safety standards.	A foreman ignores an employee who repeatedly does not use the fall restraint system provided him/her.
Safe equipment not provided	An employer does not provide an employee with equipment necessary to minimize hazards.	A foreman does not provide his/her crew members with proper fall restraint systems when such systems are needed.
Unsafe methods or sequencing	The normal sequencing of construction tasks does not occur, resulting in a task being inherently more hazardous than is typical.	A general contractor insists that a carpenter start framing before the foundation is properly backfilled.
Unsafe site conditions	The site is inherently more hazardous than are typical construction sites.	Poor housekeeping, a broken ladder, or a structurally deficient work platform
Not using provided safety equipment	An employee is provided with proper safety equipment but does not use it properly or does not use it at all.	A trained and experienced tradesperson who has been provided with an appropriate fall restraint system refuses to use it.
Poor attitude toward safety	An employee may have been properly trained, but does not properly avoid job hazards due to a ‘‘tough-guy’’ mentality, laziness, or a perception that prescribed methods would unduly slow job progress.	A tradesperson who has been trained on the proper use of ladders refuses to face the ladder when walking down it.
Isolated, sudden deviation from prescribed behavior	A normally competent and safety-conscious employee suddenly and unforeseeably performs an unsafe act due to fatigue, preoccupation, or likewise.	A trained and experienced tradesperson who has been using a proper fall restraint system suddenly forgets to tie himself/herself off.

tempts to reduce the problem by analyzing the ability of each entity that plays a major role on construction sites to influence the root causes of accidents. This theoretical analysis is based on a review of pertinent literature and the writer's training and experience as a construction project manager, expert witness, and authorized OSHA instructor). It is suggested here that all construction accidents result from one or more of the eight root causes listed in Table 2. Many of these causes are similar to those proposed by Abdelhamid and Everett (2000) and Suraji et al. (2001). Because they are behavioral, they differ substantially from the physical porcess root causes discussed by Hinze et al. (1998). As Table 2 includes a description and example for each root cause, the root causes will not be discussed in detail here. It should be noted that a key assumption by the writer that underlies the list is that the behavior of individual employees is sometimes (but certainly not always) the primary cause of an accident. This assumption conflicts with the philosophy of some safety professionals that all accidents are preventable and that all accidents are a result of management failure. Of the eight proposed root causes, the first five listed are associated with an unsafe condition that implies a deficient management of safety; the latter three listed are associated with an unsafe act by the injured party or an injured party's coworker(s).

Having identified eight root causes that lead to construction accidents, the next step in the theoretical analysis is to identify the factors necessary for an entity to prevent these root causes and therefore reduce construction accidents. These factors are summarized in Table 3 and discussed below. (This section of the paper does not attempt to identify which construction entity can or should influence these factors. Instead, the key factors are first identified. The paper later discusses which entity is best suited to influence each factor.)

Lack of Proper Training

A worker who has not been trained—either through classroom or on-the-job instruction—may not be able to recognize and avoid all potential hazards associated with the task he or she is performing. To ensure that a worker is properly trained, several factors are necessary. First, the individual(s) responsible for a worker's training must have expertise in the task being performed. (If he or she does not fully understand the desired end result of a task and the materials, equipment, and process used to achieve the end result, how can he or she adequately assess whether a worker is trained properly?) Second, the entity must have expertise in the required training requirements for the specific task being performed, which requires a working knowledge of the relevant portions of the OSHA text that apply to the task (for example, many competent journey-level workers are not aware that 29 CFR 1926 Subpart X identifies specific training requirements on the proper use of ladders). Third, the responsible individual(s) must have access to the employee's training records (if they exist) to identify what formal training the employee has had in the past. Fourth, the entity must be able to interview, test, or observe the employee in the performance of the task (or a similar task) to confirm the employee's current state of competence in safely performing the task.

Deficient Enforcement of Safety

For a number of reasons, workers do not always follow proper procedures for minimizing jobsite hazards. Although even the best site management of safety cannot prevent all accidents, entities other than those actually performing the work do have an important role to play in enforcing proper safety standards. To effectively enforce safety on the jobsite, several factors must be in place. First, the entity must be able to monitor the work on a frequent basis. Second, the entity must know the relevant safety standards for the task being performed. Third, the entity must be able to control behavior. In other words, the entity must have the formal or informal authority to direct the actions of the workers.

Table 3. Factors Needed to Prevent Root Causes of Construction Accidents

Root cause	Factors needed to prevent root cause
Lack of proper training	Have expertise in task; have expertise in training requirements; able to interview; test; or observe employee; have access to prior training records
Deficient enforcement of safety	Able to monitor work on frequent basis; know safety requirements for task; able to enforce safety
Lack of safety equipment	Know what safety equipment is required for task; able to provide and enforce use of equipment; know inspection and maintenance history of equipment being used
Unsafe methods or sequencing	Know standard methods and sequencing for task; able to observe actual methods and sequencing; able to control methods or sequencing
Unsafe site conditions	Know proper site conditions; able to observe actual site conditions; able to control site conditions
Not using provided safety equipment	Able to observe employee constantly; able to influence behavior through evaluations; and so on
Poor attitude toward safety	Interact with worker frequently; able to influence attitude through evaluations; and so forth
Isolated freak accident	Cannot predict or prevent unless employee's emotional or physical condition contributed and this condition was obvious to others

Lack of Proper Safety Equipment

Some construction accidents result, in part, because the safety equipment necessary to perform the job safely is not present at the location of the work. To control this root cause, an entity must first know what safety equipment is required for the task. Second, the entity must be able to provide the needed equipment and to enforce its use. Third, the entity must know the inspection and maintenance history of the equipment to ensure it is in sound operating order.

Unsafe Methods and Task Sequencing

Accidents occasionally are associated with a task being performed at a point in time in the sequence of construction that is not safe. While construction is an inherently dangerous process, tradespersons have developed means and methods to minimize the hazards for their task that depend on having certain activities completed before the task is started. Deviations from the safe sequence of tasks can make a task inherently more dangerous because the means and methods do not match well with the actual site conditions at the time. To control this root cause, an entity must first know the safe methods and sequencing for a task. Second, the entity must be able to determine whether the actual sequencing on a specific project is safe. Finally, the entity must be able to control the methods used to perform the task if the sequencing is not safe.

Unsafe Site Conditions

As is true for lack of training, lack of proper equipment, and unsafe sequencing, working under improper site conditions dramatically increases the chances that an accident will occur. Additional examples besides those listed in Table 2 include slippery surfaces, an excessive number of trades working in one area, and hazardous electrical and atmospheric conditions. To prevent this root cause, an entity must first know what conditions are appropriate for a task to proceed and what conditions are inappropriate. Second, the entity must be able to observe the actual site conditions while the task is being performed with regard to hidden hazards, and analyze schematic drawings or other data. Third, the entity must be able to either control site conditions or control how the work is performed given the actual site conditions.

Not Using Provided Safety Equipment

Construction accidents occasionally result from workers not effectively using safety equipment that is provided for their use. While it is impossible to eliminate such accidents, the frequency of occurrence can be reduced if an entity is able to observe workers constantly in order to immediately identify when safety equipment is not being used properly. Also, the entity must be able to influence the behavior of the worker through some sort of positive influence or verbal chastisement, written warnings, or dismissal.

Poor Attitude Toward Safety

With a small percentage of construction workers, poor safety behavior goes beyond not using the safety equipment provided them. Whether this poor attitude reflects an ''only wimps use equipment like that,'' ''I can't be bothered with that stuff,'' or ''if I do it that way I won't finish the job in time'' reasoning, such workers have never gained a full understanding that all tasks must be performed safely at all times. Preventing such an attitude from eventually leading to an accident is difficult, but the entity attempting to reduce this root cause must interact with the worker frequently and be able to improve the worker's attitude through positive or negative influence.

Isolated "Freak" Accident

The seven root causes already discussed ''point a finger'' at either poor management of safety or individuals with a propensity to violate safety standards. Some accidents do not result from either set of root causes, but instead can accurately be viewed as isolated accidents with no one individual or organization at fault. Construction is inherently one of the most dangerous occupations, and some tasks are inherently more dangerous than others. Even extremely well trained and safety-conscious individuals can be involved in an occasional accident. Perhaps the simplest example is a seasoned carpenter striking his thumb while hammering a nail. Unless a worker's obviously impaired emotional or physical condition contributed to an accident, it is not possible for any entity to predict or prevent such accidents.

The previous paragraphs have discussed the factors necessary for an entity to influence each of the eight root causes of construction accidents. The reader no doubt noticed there was substantial overlap between the factors, i.e., that several root causes shared the same or similar factors. In fact, the factors necessary for any entity to influence the root causes can be reduced to the five factors listed below. To influence all of the root causes, an entity must possess

- Expertise in each task,
- Expertise in the safety requirements for each task,
- Ability to evaluate the work and site conditions,
- Ability to interact with workers and control their behavior, and

• Ability to control all work on the jobsite and the jobsite itself.

Analyzing Ability of Each Entity to Control Root Causes

Having identified the factors necessary to influence root causes and therefore reduce construction accidents, each factor will now be briefly analyzed as to how it applies to the entities typically involved in construction projects. In other words, this section discusses each entity's ability to control root causes by analyzing how much the associated factors apply to each entity on a typical project. The analysis will first assume the traditional contractual structure, where the owner hires a general contractor to oversee the construction after he or she has hired an A/E to design the project and to perform traditional construction services. Specifically, it is assumed that the A/E's construction services include reviewing submittals, responding to requests for clarification, and making occasional inspections to ensure that construction is in conformance with contract documents and that requests for progress payments are reasonable. It is also assumed that the A/E is not responsible for ensuring that construction progress is acceptable, that the A/E does not direct the means and methods, and that the A/E cannot stop the work for any purposes other than conformance with contract documents. How the analysis applies to alternative project arrangements such as design/build is discussed later in the paper.

As is true of all frameworks and models, the analysis performed here simplifies reality in order to better understand it. The analysis requires making generalizations about each entity, which is dangerous because changes in the construction industry over the past 30 years have somewhat blurred the traditional roles of each player. Furthermore, many companies play different roles on different projects. A company actually performing the work can be a subcontractor on one project and a prime contractor on another. A contractor can be a general contractor performing some of the work on one project and a pure construction manager on another. An engineer can be a pure design engineer with no field observation responsibilities on one project and part of a design/build team on another.

The results of the analysis are therefore appropriately applied to a company for an individual project, not all of the projects a company is involved in. That is, the analysis indicates the safety roles a firm should play on a specific project, given the specific operational role it is playing on that project. A firm can therefore be expected to play different site safety roles from one project to the next, depending on its operational activities.

With that preamble, let us now consider each of the site safety factors listed above and the extents to which they apply to subcontractors, GCs, A/Es, and owners. The reader will note that this analysis is a practical one. That is, the analysis is based on actual processes (i.e., the way it actually happens in the field), OSHA requirements, or economic considerations that entities should consider to maximize profits. The analysis does not rely on moral or ethical grounds.

Task Expertise

On the majority of construction tasks performed today, expertise in a task resides only within the subcontractor actually performing the task (it should be noted that in this paper, GCs are considered in-house subcontractors for the phases of work they self-perform). One of the most fundamental trends in construction over the past 50 years has been increased task specialization. Increased levels of competition within regional markets have mandated that construction crews be as efficient as possible. As a result, most construction workers no longer perform the range of tasks associated with their trade; rather, they specialize in a narrow range of tasks using the most efficient tools, materials, and methods. For example, a carpenter might specialize in installing roof sheathing and will rarely be asked to perform all rough carpentry tasks, much less any finish carpentry work. A journey-level cement finisher will specialize in operating a motorized trowel and rarely participate in placing, screeding, or floating concrete. Construction trades persons and their foremen therefore possess deep tacit knowledge about their specific tasks that others on the site lack.

Table 4. Typical Ability to Affect Root Causes for Each Entity

Factor necessary to affect root causes	Subcontractor	GC/CM	A/E	Owner
Task expertise	High	Moderate	Mixed	Low
Safety expertise	High	Moderate	Low	Low
Worker interaction and control	High	Moderate	Low	Low
Control site	Moderate	High	Mixed	Mixed
Evaluate site conditions	Mixed	Mixed	Mixed	Low
[Aggregate ability to influence root causes]	High	Moderate	Mixed	Low

GCs can typically be expected to have a moderate level of task expertise. Twenty or more years ago, the GC's superintendent usually had fairly deep knowledge of nearly all construction tasks because he/she typically had worked his/her way up from a construction trade. Also, because GCs often self-performed all phases of the work except for the utilities, the superintendent played an active role in directing the hour-by-hour field operations. Currently, most GCs subcontract out all of the 20–50 phases of construction except for two or three, and GC field engineers are often recent engineering graduates who possess little tacit construction knowledge.

Most A/Es have less construction task expertise than GCs because they have spent considerably less time on construction jobsites. They may be in a position to analyze one portion of certain construction tasks—such as designing falsework or scaffolding—but they lack the tacit knowledge of how the falsework or scaffolding is used on a minute-by-minute basis to accomplish the work. Similarly, A/Es may better understand the basis for concrete mix designs and the deleterious effects of a high water-cement ratio, but they know little about deploying a crew to execute the placement and finishing of a concrete slab. The vast majority of owners have even less expertise than A/Es because they neither spend much time on a jobsite nor have received the technical training that design professionals receive.

This brief and crude analysis is summarized in Table 4. In short, subcontractors are ascribed to have high task expertise, GCs are ascribed moderate task expertise, A/Es are shown to have mixed expertise (moderate on some tasks and low on others), and owners are ascribed to have low task expertise.

Safety Expertise

Subcontractors are ascribed a high level of safety expertise because it is their employees who are most exposed to hazards on the jobsite, and paragraph 1926.21(b)(2) of the 2000 OSHA CFR requires them to train their employees on recognizing and avoiding hazards. GCs are ascribed a moderate level of safety expertise for three reasons. First, they usually have some employees continually on-site who may be exposed to hazards as part of their oversight function. Second, GC employees may potentially be in a position to recognize a hazard and prevent an accident, again associated with their oversight function. A third and practical reason is that GCs want to prevent all accidents because they often slow project progress.

The expected level of safety expertise for A/Es is mixed. On one hand, they have no employees exposed to hazards except during short and infrequent inspections to monitor that the construction conforms to the project documents. Also, A/Es typically do not receive OSHA training as part of their education or experience [Gambatese (2000) and others have argued that A/Es should receive construction safety training because that might cause them to consider safety during design]. On the other hand, A/Es typically possess knowledge of engineering that provides insight into site safety matters such as excavation cave-in protection, bearing capacity of soils and structures, and scaffolding and falsework design. In the survey discussed earlier in this paper, the percentages of respondents who did not agree with the statement that ''A/Es are typically familiar with OSHA requirements'' were 53, 88, and 64% for A/Es, GCs, and subcontractors, respectively.

The expected level of safety expertise for owners is low. As is true of A/Es, they have no employees exposed to hazards except perhaps while monitoring progress, and they do not receive any safety training. The expectations concerning safety expertise are summarized in Table 4.

Evaluation of Site Conditions

Subcontractors' ability to evaluate site conditions for unacceptable hazards varies with the type of hazardous condition. Subcontractors can be expected to observe the work and the jobsite at all times because it is their employees performing all of the actual construction work, and paragraph 1926.20 of the OSHA CFR requires ''frequent and regular inspections of the sites, materials, and equipment to be made by competent persons designated by the employers.'' Also, subcontractor foremen and other managers observe the work regularly to ensure that the work is accomplished within productivity and quality goals. Subcontractors therefore have a high ability to identify visible unsafe conditions such as broken ladders and slippery surfaces. On the other hand, subcontractors may have a low ability to identify hidden unsafe conditions, such as structurally deficient work platforms or hazardous electrical or atmospheric conditions, unless these conditions are routinely faced in their work.

The ability of GCs to evaluate potentially unsafe conditions is similarly mixed. GCs have a high ability to evaluate visible unsafe conditions because it is custom and practice that a GC representative be responsible for the overall jobsite when several subcontractors are working on-site (furthermore, many construction contracts explicitly require that the GC be present when any work is being accomplished, even if only one subcontractor is working). GCs are also expected to observe the jobsite on a frequent basis to ensure that progress and conformance with specifications are satisfactory. On the other hand, GCs also typically have a low ability to evaluate hidden unsafe conditions such as structurally deficient work platforms or hazardous electrical or atmospheric conditions.

The ability of A/Es to evaluate unsafe site conditions also depends on the type of condition, but the reasoning is different from that for GCs and subcontractors. A/Es' ability to identify visible unsafe conditions is low because they are on-site so infrequently. A/Es' ability to identify and prevent some hidden unsafe conditions, on the other hand, may be higher than the abilities of subcontractors or GCs. Specifically, A/Es are in the best position to implement the specific safe design recommendations reported by Gambatese et al. (1997), thereby preventing the need for some less safe conditions to be present on the site. Also, A/Es may be best able to identify questionable structural situations such as temporary loadings on the permanent structure or temporary work platforms, provided they are explicitly requested to do so and possess all of the data necessary to perform the analysis. Safety liability associated with shop drawing review is a salient issue within the A/E community, and is likely to be addressed in future revisions to the ASCE Policy Statement 350. The ability of owners to evaluate unsafe conditions is low because they typically lack the site presence and expertise to identify both visible and hidden unsafe conditions.

Worker Interaction and Control

Because it is subcontractor employees who are performing the work, it is clear that subcontractors have the highest level of worker interaction and ability to control behavior. Frequent interaction between foremen, other managers, and site employees is necessary to ensure that productivity and quality are maximized. Particularly for open-shop tradespersons, their continued employment, wages, and bonuses depend on their obeying company policies and the direction given by their supervisors.

The levels of worker interaction and ability to control behavior by GCs are moderate. On one hand, GCs typically monitor quality and progress through occasional cursory inspections and discussions with foremen rather than through interacting directly with the workers. Indeed, a subcontractor would likely complain if a GC were interacting frequently with workers during the performance of the work because it would likely lead to conflicting directions and hamper productivity. On the other hand, it is custom and practice and in most subcontracts that the GC can direct a subcontractor foreman to remove specific workers from the site due to unacceptable work or behavior.

For A/Es, the level of worker interaction is low. Their interest in ensuring construction quality is best served by occasional cursory monitoring of the work in progress and discussions with the GC or occasionally with a subcontractor foreman, not with the workers themselves. Again, a subcontractor would complain if an AE were substantially interacting with the workers because it would hamper productivity. Model General Conditions, such as the AIA 201, explicitly state that the A/E shall not be responsible for supervising the work or directing means and methods (Toole 2002).

The level of owner interaction with subcontractor workers depends on the type of owner. As is true for A/Es, most owners only perform cursory monitoring of the work and interact with the GC or subcontractor foreman, not with the workers themselves. Some owners, however, have special sanitary or operational procedures (such as the military and processors of food or hazardous materials) that are strictly enforced by trained in-house representatives, occasionally through direction given to the workers themselves.

Control over Site

The level of subcontractors' control over jobsite conditions such as layout, temporary utilities, housekeeping, and nearby operations depends on the subcontractor's trade. Subcontractors performing demolition, excavation, or foundation work have a high level of site control because they often work alone on the jobsite, without other subcontractors or even the GC present. The level of site control for most subcontractors, however, is low because they work mostly when other subcontractors and the GC are also on the jobsite. It could be argued that even these subcontractors have some control over the site conditions because they could refuse to perform their work until the site was cleaned up, better shared equipment such as ramps and ladders were provided, or a fewer number of trades were working in the same place. The practical reality, however, is that most subcontractors do not want to refuse the directions of the GC, and will compromise their site conditions standards if necessary.

The level of site control for GCs is very high because they are explicitly tasked with monitoring and coordinating the work of the subcontractors. GCs alone can direct the overall work of the subcontractors, including site layout, housekeeping, and the pace of construction (notwithstanding the fact that direction that conflicts with the subcontract or with custom and practice can result in change orders or claims). Furthermore, GCs frequently provide equipment and facilities that are shared by subcontractors, such as ladders, scaffolding, ramps, and dumpsters.

The practical ability of A/Es to exercise control over the jobsite is mixed. On one hand, A/Es typically lack the authority (based on typical General Conditions), expertise, and continuous site presence to control the site. They rarely become involved in decisions involving site layout, scheduling the trades, or housekeeping. On the other hand, as Gambatese (2000) and others have pointed out, key design decisions by A/Es can substantially influence what must be accomplished on-site.

As is true for worker interaction, owners' level of site control depends on the type of owner. Most owners lack the knowledge and staffing to exercise any control over the jobsite. Some large owners have special sanitary or operational procedures that result in trained in-house construction representatives frequently becoming involved in site control matters. Table 4 summarizes the extent to which each entity can control the site.

Other Entities and Special Conditions

As stated earlier, the analysis thus far applies to projects in which the owner, A/E, and GC each play their typical roles in the design-bid-construct process. On an increasing number of projects, one or more of these entities are not present or play an expanded role. The ability of each entity to influence root causes of accidents will be very briefly discussed here. In addition, the roles of subcontractor employees and material vendors are touched upon.

One alternative project arrangement is the construction management model where the CM replaces the GC and upper-tier subcontractors function as prime contractors. The range of operational duties that CMs may assume varies more widely than the range of duties that GCs assume. Generalizations are difficult beyond the facts that CMs rarely self-perform any work and always act as sophisticated owners' representatives to manage the work performed by multiple prime contractors. There are CMs who look out more for the owners' interests and get involved earlier in the project planning and design process than do typical GCs. There are also CMs who are just sophisticated owners' representatives during construction. In general, however, when compared to GCs, CMs can be expected to have

- Slightly lower task expertise (because they have broader responsibilities for the design and construction process, and typically less field experience),
- Same level of safety expertise (unless their contracts with the owners explicitly absolve them of safety responsibilities),
- Slightly lower site presence (because prime contractors are expected to run their portions of the project without oversight),
- Same level of worker interaction and control (because they interact with the prime contractors' foremen), and
- Same level of site control.

A second fast-growing alternative project arrangement is that the separate A/E and GC are replaced by one design/builder. The expectations toward site safety responsibilities for design professionals associated with the design/builder—even if they are only part of a joint venture or a temporary, informal partnership—would reasonably be viewed as those of a CM or GC.

A third alternative project arrangement involves no external GC or CM. Instead, an owner with in-house construction management expertise contracts with multiple prime contractors to accomplish a project. With this arrangement—which clearly deviates from the hands-off role that owners traditionally play in construction—it would be reasonable to assign to the owner the same safety responsibilities as those of an external CM.

It should be noted that the analysis has omitted two entities involved in the construction process. The discussion thus far has included the employers of the workers actually performing the work (referred to as subcontractors) but not the workers themselves. An individual worker's task expertise is nearly always much higher than that of GCs, A/Es, and owners, but his or her safety expertise may not be higher. Indeed, seasoned representatives of GCs, A/Es, and owners may have had more exposure to safety standards than new construction workers who have not been properly trained. Because individual workers are the ones actually performing the work, they rate highly in site presence and worker interaction and control. Their ability to control the site, however, is generally quite low.

The second entity that has been omitted from the analysis is material suppliers, which include manufacturers and retailers that deliver steel, lumber, windows, drywall, etc. (turnkey suppliers that also install the materials are considered subcontractors). While the task expertise and safety expertise of office managers and outside salespersons may be mixed, the expertise of the employees delivering the materials is generally quite low. The factors relating to worker interaction and site presence are low because material suppliers are so infrequently on-site. The factors relating to controlling worker behavior and controlling the site are both low because material suppliers lack both the needed expertise and the authority.

Conclusions and Applications

This paper has attempted to reduce the uncertainty among design and construction professionals about site safety roles by theoretically analyzing their respective abilities to influence the root causes of accidents. The analysis (summarized in Table 4) indicates that under the traditional design-bid-construct project arrangement, subcontractors have a high ability to influence root causes, general contractors have a moderate ability to influence root causes, A/Es have a mixed ability to influence root causes, and owners have a low ability to influence root causes.

It is hoped that the analysis will serve several purposes. One purpose is to stimulate discussion that may lead to permanent changes in the industry, such that all future construction projects will have detailed expectations on respective safety roles clearly articulated before the site work begins. Such expectations should be in writing (probably in the supplemental conditions) and reflect the same level of exacting detail found in technical specifications and in general conditions clauses on progress payments, submittals, and likewise.

Site safety expectations should also be practical. That is, they must reflect the actual abilities of each company to prevent the root causes of accidents discussed in this paper. For example, it would not be appropriate to assign substantial safety responsibility to an A/E who is being paid to be on-site during construction only for occasional quality inspections because such a company would have little control over any of the factors needed to prevent accidents.

Finally, site safety expectations should be project and company specific. For example, an engineering firm might team up with a general contractor on a design/build contract. Absent specific contract language, a design engineer could be assumed to have the same ability to control the work when he/she is on-site that the general contractor has. Yet it is highly likely that the engineer possesses nowhere near the same understanding of the construction process or safety standards that a general contractor's seasoned superintendent possesses. The limited role that design engineers can typically play in site safety should be specifically acknowledged in the joint venture agreement between the engineering firm and the general contractor, and perhaps in the contract between the owner and the joint venture.

A second purpose of this paper is to facilitate fair postevent analysis by entities outside of the construction industry, namely civil courts and OSHA. This paper suggests that—absent clear and detailed discussion in contract documents—the level of site safety responsibility ascribed to each entity should reflect their actual ability to influence root causes. The analysis points to the need to consider the specific root causes involved in an accident, and who could have influenced those root causes. For example, an A/E performing traditional construction services typically has little real influence on the root causes of any site accidents, even if the contract vaguely allows him or her to stop the work. Even a seasoned GC superintendent can do little to prevent an accident when influencing the root cause requires task and safety expertise that the superintendent cannot reasonably be expected to have.

All organizations and individuals involved in construction projects should be actively concerned with the safety of the workers performing the actual construction on-site. Establishing realistic, shared expectations about the safety role that each entity can play will reduce the current uncertainty within the design and construction community, allowing entities to better focus on the roles they can realistically assume. Ultimately, shared expectations will help prevent some accidents from occurring and improve the overall level of safety on construction sites.

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