Volume 2
Number 2

Summer 1997

The Journal of Construction Education

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Thomas H. Mills, ***Associate Editor***

A TRI-ANNUAL PUBLICATION OF
THE
ASSOCIATED SCHOOLS
OF
CONSTRUCTION

ISSN 1522 8150

Host Journal of
The Associated Schools of Construction
Building Science Department
119 Dudley Hall
Auburn University
Auburn, AL 36849-5315
Tel: 334.844.4518
E-mail: molhend@mail.auburn.edu

Journal Published by
Illinois State University
Turner Hall, Room 210
Normal, IL, 61790-5100
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The Journal of Construction Education

Summer 1997

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Number 2
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Journal of Construction Education
Summer 1997, Vol. 2, No. 2, pp. 84-90

1522-8150/97/$3.00/Educational Practice Manuscript

Measures of Student Empowerment, Attitude, and Motivation Toward Construction Education and the Profession

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This study investigates the relationship between student empowerment, attitude and motivation toward construction management course work and professional construction management. The primary purpose of this study is to conduct an investigation of the elements that are influential in forming and predicting the attitude and motivation of students.

Key Words: Attitude, Empowerment, Motivation, Construction Education

Introduction

The impetus for this research arises from a general concern with the lack of available instrumentation or measures of student attitude and motivation within construction education. Students' feelings of empowerment or personal control within construction education course work and toward the construction management profession have not been documented within the current body of construction education literature. The primary purpose of this study is to conduct an investigation of the elements that are influential in forming and predicting the attitude and motivation of students. The results of this investigation should provide educators with specific elements that will enhance their instructional strategies and assist in the students' professional transformation.

Rationale

Today, job differentiation, which is created by a specific education-socialization process and reinforced by a distinctive set of skills and language, is the hallmark of a professional and a professional's cultural climate (Bennett & Wittaker, 1994). Cultural values and opinions are developed through maturation, and influence a student's perception and desire to enter into a specific profession. The Wyatt Company survey (1989) associates attitudes and professional values with perceptions of work and careers in society. In a study of self-concept and change, it was found that attitudes are more likely to be affected by the internalizing of public opinions than any other personal trait (Tice, 1992). More often than not, the public's opinion of construction is not generally positive. "If no other work exists, there is always construction." The public culture has not been kind, and we within construction often do nothing to modify the public perception of our public value and commercial success.

Bennett and Wittaker (1994) studied the differences between physical scientists, architects, and engineers. The work of the physical scientist is usually withheld from the public view by being confined to an industrial or academic laboratory space. However, the public was found to express confidence or prestige in the scientific community because it was deemed that a highly trained public determines and reviews their performance (Bennett et al., 1994). Cultural opinion holds high expectations for scientific problem-solving to discover and invent solutions that answer problems (Bennett et al., 1994). Given the cultural emphasis on science in academic programs and society, the pattern of public interest is not surprising.

Allen's study (Allen, 1984; cited in Bennett et al., 1994) states that engineers differ from scientists in their professional activity, attitudes, orientation, and typical family background. The construction related professions of the architect and engineer were described as being publicly related or involved. A high level of aesthetic interest and evaluation of the architecture/engineering type professions was felt to exist in society. If a public or private facility was not within the public’s taste, its negative review occurs daily. The study further found that architecture/engineering was being judged by an untrained public culture that has little understanding of the processes involved with an artistic or unstructured solution-focused discipline. The design professions are therefore seen to be fairly open-minded and artistic, but exhibiting a need for acceptance and recognition from a broad public.

Professional construction management has not been evaluated by the public culture to date. However, in some public opinions, professional construction is perceived as mostly including individuals who are stubborn, physical slobs, contractual cheats, sexist, and always unclean or dirty. Cultural understanding about certain disciplines within construction is affected by the information available to the public (Young, 1989; cited in Young and Duff, 1990). Within professional construction, as opposed to the design professions, there is little public evaluation or praise concerning value to the common society. Corner stones, most often, do not list the building’s constructor. It often seems attitudes shaped over many years of learning and experience are not usually all that flexible, the impact of negative cultural opinions cannot be disregarded within construction education or profession.

Recently, Sidlik and Pilburn (1993), presented data on the development of a Likert-type instrument which investigated the relationship between student empowerment and attitude toward science. Sidlik et al. provided evidence that indicates a very strong relationship exists between student perceptions of control and attitude toward science and science education. This study reconfirmed the ideology that a classroom climate can be useful in predicting the students' attitudes toward science. Factors of attitude and empowerment in the academic atmosphere were identified as performance and motivation that related to student cooperation/competition and student/instructor control. The assumption of the study was that students were interested in issues concerning the decision-making process in the classroom as they progressed in their scholastic development. The current study borrows from Sidlik and Pilburn’s work by choosing their instrument for modification and use in this study. The investigators of this study chose to adapt their instrument rather than develop a new instrument. An adapted instrument borrows the strength of the original instrument’s development process, subsequent research, and data analysis into validity and reliability.

Cognitive theory links the constructs of attitude and motivation with the dimensions of intrinsic or extrinsic empowerment. The current study defines motivation as an achievement-related belief that affects goal directed activities in the immediate environment, i.e. gain social recognition, to please parents, or achieve good grades. Attitude is defined as an enduring disposition …positive or negative… toward a social or psychological object, i.e., feelings of like or dislike, to enjoy or hate, a state of physiological arousal expressed by a value index. The dimension of intrinsic empowerment is defined as the condition where individuals perceive themselves to be engaged in behaviors for their own reasons, i.e., interest in activity, believed to be more enjoyable, individually valued. Whereas, extrinsic conditions exists where the individual perceives themselves to be engaged in behaviors as the result of anther's reason, i.e., to please a person in authority, to escape punishment, or to obtain a reward.

This study was to investigate the relationships between student empowerment, attitude and motivation toward construction management course work and professional construction management. Key to this investigation was the identification of those factors that are influential in the prediction of students' feelings of empowerment within their construction course work.

Methodology

The instrument was administered to college students (n=176) taking construction management courses at nine four-year universities. The universities were Illinois State University, John Brown University, Louisiana Tech University, Louisiana State University, North Lake College, Oklahoma State University, Texas A&M University, University of Arkansas, and University of Texas.

The questionnaire is constructed in three parts entitled: 1) Acknowledgment of Participation, 2) Attitude Toward Learning, and 3) Background Information. The acknowledgment gave the intention of the study to the students, and also, required a signature of their consent for participation. The background obtained variables of the colleges construction focus, gender, age, academic major, academic classification, grade point average, whether attended college for construction education, construction work background, time sense last construction employment, perception of management abilities and perception of practical technical abilities. The questions in the survey consisted of thirty items regarding construction course work and construction management. Items were measured on a five-point Likert-type scale: 1 = "Strongly Agree", 2 = "Agree", 3 = "Undecided", 4 = "Disagree", and 5 = "Strongly Disagree". The statements were derived from the instrument *My Science Class* (Sidlik et al., 1993). To modify this instrument for use in our curriculum area the word "science" was replaced with "construction," i.e., in the place of "Science lessons are enjoyable for me" this study used "Construction classes are enjoyable for me," or "I would like to be a scientist some day" became "I would like to be a construction manager some day" (see Appendix A).

A second survey was then conducted at Illinois State University to determine the theoretical category of the thirty questions and to provide construct validity within the modified questions. Professors within the Industrial Technology Department were given cognitive element definitions and asked to check which elements applied to each question. The results of this instrument are listed in Appendix A.

Data Analysis

A principal component factor analysis on SPSS reveals four factors among items on the instrument Attitude Toward Learning Construction, and has tentatively been labeled: Intrinsic Attitude (Factor 1) 16 items, Group Motivation (Factor 2) 5 items, Extrinsic Motivation (Factor 3) 5 items, and Intrinsic Motivation (Factor 4) 4 items (see Appendix A).

Factor 1, Intrinsic Attitude, is interpreted as seeing, hearing, and experiencing internal beliefs, thoughts perceptions that an individual uses as a measure for succeeding while attempting to achieve their academic or professional goals. Items consist of statements that respondents' appear to feel represent a way individual students have a common persona.

Factor 2, Group Motivation, contains items that mention academic classroom involvement, respect, and togetherness. Students appear to look at their mentors, role models, and peers for self assurance and guidance, which may be a desire for approval, from sources that accept construction management as a profession and discipline. Working with others in the academic environment is perceived as an internal pressure for increasing self-esteem and accomplishing goals. There, then, may be a sign of competitiveness that serves as a check and balance of internal attitudes that have an objective for becoming the best construction manager.

Factor 3, Extrinsic Motivation, comprises items that elude respondents to experience pressure to do well within the scholastic environment (together as a class and individually). Students reveal academic mentor challenge their self-concepts of a construction manager. Academic mentors are respected as in Factor 2 with the exception that now they may be thought of as goal setters and as a first professional construction manager outside source to assess a student's potential. The measure of success appears to have a predictive weight determining a students potential of becoming a construction manager.

Factor 4, Intrinsic Motivation, consists of items reflecting an internal desire to become a successful construction student. Students seem to want to belong to a group working toward a similar goal, that is, to become a construction manager. Peers appearing to have similar goals seem to affect a student's self-concept that construction management is a respectable academic program. As a student senses a need to be part of a group, they appear to develop an internal desire to accomplish tasks expected for becoming a construction manager.

Once factors were labeled, a 4 x 7 stepwise linear regression on SAS was conducted with the continuous variables that would report what elements predict each factor. This procedure estimates the coefficients of the linear equation, involving a set of independent variables, which best predicts the value of the dependent variable. The dependents were means of each of the four factors for each subject. The independent variables were age, construction work background, academic classification, grade point average, time sense last construction employment, perception of management abilities and perception of practical technical abilities. The data analysis revealed significant prediction for all factors.

Factor1, intrinsic attitude by perception of practical technical abilities yielded a significant correlation (F=.0007). Factor2, group motivation by perception of management abilities, age, and academic classification all were significant predictors, (F=.0018), (F=.0031), (F=.0289) respectively. Factor3, extrinsic motivation by academic standing was significant, (F=.0325). Factor4, intrinsic motivation by perception of management abilities was significant, (F=.0015).

Conclusions

The prediction within Factor1 indicates that, as a student's perceptions of their practical abilities increases so does their personal attitude toward construction course work and professional construction. This gives support to the practice of programs requiring students to take internships or work at construction during the summer months. Practical experience it seems, is not only the best teacher, but, also provides students with an enduring disposition and excitement toward success in their own course work and profession choice.

Factor2 has several predictors. Two of the variables, age and academic standing, are similar enough to group together. That is, students do get older as their academic careers progress. The data indicates that as students mature and advance toward graduation their belief that goal directed behavior will lead to success increases, as does the perception of their management skills and abilities. This belief is not only held about themselves, but about construction students as a whole.

Factor3 predicts that as students progress toward graduation they will feel more outside pressure to do well in their course work. Students also felt more comfortable with the direction their professors were leading them and the construction program.

Factor4, intrinsic motivation by perception of management abilities predicts that students themselves feel responsible for their own success. They like themselves and the direction they are going professionally.

The overriding indication from this study seems to be that students indeed do enter into the construction coursework with poor attitudes and motivation concerning their educational standing and the value of a construction profession. However, as they progress toward graduation this belief system is modified to be a responsible positive outlook to their future, not only in construction education, but for construction as a profession of choice.

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Appendix A

Factor Analysis

FACTOR 1 Intrinsic Attitude									
1	Construction classes are enjoyable for me.	0.64	-0.02	-0.07	0.39	Intrinsic	Academic	Self	Attitude
23	We (the students) feel that construction lessons are enjoyable.	0.64	0.17	-0.13	-0.07	Intrinsic	Academic	Group	Attitude
25	I would like to be a construction manager some day.	0.61	-0.22	-0.09	-0.04	Intrinsic	Profession	Self	Motivation
17	I like construction more than other students.	0.60	-0.28	0.12	-0.15	Intrinsic	Profession	Self	Attitude
20	I like reading about construction in books, magazines, and newspapers.	0.60	0.11	-0.07	-0.12	Intrinsic	Profession	Self	Attitude
19	Most of the other students in my class like construction.	0.59	0.23	0.15	0.09	Intrinsic	Profession	Group	Attitude
14	I don't like construction classes.*	-0.57	-0.10	0.16	0.22	Intrinsic	Academic	Self	Attitude
21	Other students would like me as a business partner.	0.52	-0.01	-0.02	-0.06	Extrinsic	Profession	Self	Motivation
2	We (the students) see this construction class as being worthwhile.	0.52	0.15	-0.21	0.44	Intrinsic	Academic	Group	Attitude
27	Technical construction is easy for me.	0.51	-0.35	0.17	0.20	Intrinsic	Profession	Self	Attitude
29	We (the students) feel that construction courses should be enjoyable.	0.49	0.16	0.04	0.14	Intrinsic	Academic	Group	Attitude
8	We (the students) take a positive attitude toward our construction classes.	0.48	0.39	0.07	-0.11	Intrinsic	Academic	Group	Attitude
26	Construction is an easy subject for me.	0.48	-0.40	0.14	0.10	Intrinsic	Academic	Self	Attitude
6	My friends are better at construction than I am.*	-0.46	0.35	0.09	0.28	Intrinsic	Profession	Group	Attitude
7	I think other students in class like construction more than I do.*	-0.45	0.37	0.23	0.32	Intrinsic	Academic	Group	Attitude
30	I think other students will make better constructors than I will.*	-0.41	0.36	0.25	0.31	Intrinsic	Profession	Self	Attitude
FACTOR 2 Group Motivation									
11	We (the students) respect our construction instructor.	0.22	0.51	-0.28	0.39	Intrinsic	Academic	Group	Motivation
18	I am better than other students in construction.	0.44	-0.48	0.13	0.19	Intrinsic	Profession	Group	Attitude
12	We (the students) would like the opportunity to get to work with everyone in this construction class before the end of the semester.	0.40	0.47	-0.07	0.11	Extrinsic	Academic	Group	Motivation
5	I think other students' parents encourage them to do well in construction.	0.31	0.42	0.32	-0.07	Extrinsic	Profession	Group	Attitude
24	Other students in my construction class spend more time on construction homework than I do.*	0.04	0.27	0.21	-0.01	Intrinsic	Academic	Group	Motivation
FACTOR 3 Extrinsic Motivation									
28	My construction instructor does not know what I like about construction.*	-0.12	-0.13	0.69	0.12	Extrinsic	Profession	Self	Motivation
22	Our construction instructor does not know what we like about construction.*	-0.17	-0.21	0.62	0.03	Extrinsic	Profession	Group	Motivation
9	I feel pressure to do well in construction classes.	0.37	0.13	0.50	-0.21	Extrinsic	Academic	Self	Motivation
15	We (the students) feel pressure to do well in this construction class.	0.45	0.34	0.49	-0.22	Extrinsic	Academic	Group	Motivation
4	We (the students) feel that construction is a waste of time.*	-0.03	0.04	0.33	0.28	Intrinsic	Profession	Group	Motivation
FACTOR 4 Intrinsic Motivation									
10	I get good grades in construction classes.	0.45	-0.28	-0.04	0.60	Intrinsic	Academic	Self	Motivation
3	I would like to belong to a student construction organization.	0.50	0.19	0.06	-0.52	Intrinsic	Profession	Self	Motivation
16	Students prefer to work alone in this construction class.*	0.17	-0.28	0.19	0.45	Intrinsic	Academic	Group	Motivation
13	Constructors like music as much as other people.	0.20	0.29	-0.04	0.31	Intrinsic	Profession	Group	Motivation

Journal of Construction Education
Summer 1997, Vol. 2, No. 2, pp. 91-98

1522-8150/97/$3.00/Educational Practice Manuscript

Motivation: Dispelling Some Management Myths: An Analytical Critique

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The paper presented will analyze and discuss several common beliefs about motivations that are held by managers in various work settings. Behavior analytic principles and research will be used as reference for the analyses and discussions. The position taken is that several of the common beliefs are not supported by either casual or empirical observation. Alternative explanations end applications, supported by a body of research in the field of behavior analysis, will be offered.

Key Words: Motivation, Rewards, Goal Setting, Competition, Threats, Incentives

Introduction

All of us who work with others in a supervisory or management role have encountered difficulties in motivating people to do the work we need them to do. We also have our viewpoints on what motivation is, and what our responsibility is in motivating others. This paper will discuss some common Behavior Analytic perspectives regarding motivation in the work place. It will offer some critical analyses of those beliefs and some alternative ways of thinking about motivation and how to motivate. The ideas put forth have been studied extensively in both laboratory and field studies including studies in various business and industry settings (Daniel,, 1994; Daniels,, 1989; Gilbert, 1978; O'Brien, Dickinson, and Resow, 1982; Skinner, 1969).

Myth #1: Goal setting is a great motivator

Most successful people commonly use goal setting. The tools of organizing, prioritizing, and planning generally aid them in more efficient and/or more productive performance. It would seem, then, that goal setting would serve as a valuable motivator f or optimizing performance (Fellner & Sulzer-Azaroff, 1984). Because of this notion, management programs that employ goal-setting strategies, such as Management by Objectives (MBO), have been widely implemented. The success of such programs is generally not of the magnitude, as one would predict. Why? In park because effective goal setting is a somewhat difficult skill involving identifying the right goals and determining the right objectives. Many, through lack of experience at setting appropriate goals and objectives, set unrealistic goals and objectives and, thus, doom themselves to failure. They are not able to meet the goals and objectives they outline. When this occurs, they not only experience the personal disappointment inherent in failing, but they also tend to incur criticism and perhaps other punitive consequences from superiors. This experience, instead of motivating the individual to perform better, tends to discourage both goal setting and other work performance (Fellner and Sulzer-Azaroff, 1984). If given a choice, the individual is not likely to choose to use the goal setting strategy because using it did not 'payoff'. Further, the experience of having set goals and then failing to achieve them, points out what was not accomplished and thereby limits what the individual will attempt in the future.

Even when goal setting is used successfully to plan and prioritize tasks that are accomplished, it is not the goal setting that is the motivator. It is the attainment of goals (Fellner and Sulzer-Azaroff, 1984; Huber, 1985-1986) that will motivate individuals to: 1) continue to set goals and 2) perform well. When an individual reaches a goal or completes an objective, there is recognition of accomplishment and feeling of success that the individual most likely experiences. Further, superiors tend to be pleased with the achievement and may commend the individual or at least find fewer faults in what they have done. The accomplishment itself, the joy of accomplishment and the acknowledgement of the accomplishment by others is what motivates the individual to continue to work hard and do well.

Myth #2: Workshops/seminars/meetings are great motivators

Many managers and supervisors believe that attending inspirational workshops, seminars and meetings is a great way to motivate people to work harder and better at their jobs. After all, they contend, one has only to observe how excited the attendees are and listen to the great, new ideas that they bring back from the event to know that they are now highly motivated to excel at their work. There is some truth to this in that when individuals come back to work after listening to charismatic presenters, there is a definite tendency for there to be some renewed vigor in doing their work and in trying out the new ideas that they learned. Unfortunately, this surge in performance is generally short lived (Johnson, 1975). After a few days or perhaps a few weeks, the individuals slip back to their former levels and habitual methods. Why? Because usually they experience that it just isn't worth the effort to continue doing more or working harder. They experience that, despise the fact that they are getting more done or doing better quality work, they are not getting paid more nor even being recognized more for their extra efforts. Unless, there is a personal satisfaction that they derive from performing more effectively or more efficiently, there simply is no motivation to continue working harder.

Although, as discussed above, workshops, seminars, and meetings are not, in and of themselves great motivators, they can be used as motivators. One way is to reward people who are doing well with the opportunity to attend the event. Thus, they would earn the privilege of attending the workshop, seminar, or meeting by performing well. This won't work for every individual, but will word for those who would enjoy the break from the routine, would not be overwhelmed with work that piled up in their absence, and would get paid for their time while at the event. Another way to enhance the motivational aspects of workshops, seminars and meetings is to make sure that individuals who do implement ideas and perform better once they return, receive feedback, acknowledgement, and perhaps other rewards for the improvements. Thus, they will experience some benefit for their increased efforts and will be more likely to continue to work at the higher level.

Myth #3: Competition is a great motivator

Many analogies have been made between sports scenarios and work place scenarios. One factor that is a critical element in the sports arena is that of competition. In sports, individuals seek to be better at their events, or in their team positions, than other individuals, and teams strive to defeat the opposing teams. All in all, the participants are striving to do their best and to win. On the surface, this concept of competition seems like a valuable tool to implement in the workplace. The logic is that competition (in sports) leads to individuals striving to do their best; in the workplace we want people doing their best; thus, using competition in the workplace will lead to employees striving to do their best. What has been left out of this line of thinking and where the critical error lies, is in the observation that people compete to win Inherent in competition that pits individuals against other individuals, is the fact that only one individual, or one team, can win. All of the other competitors, thus, lose. In the workplace this can be disastrous. Especially if winning will result in some highly desirable prize, competition sets the stage for an individual doing what ever it takes to win. This not only means doing the best that they can do at their job, but it also can mean sabotaging the opponents. When the opponents work within the same company, this is an obvious problem.

A second way that competition is harmful in the workplace is that losing or failing, especially when trying to do their best, is very discouraging for many, if not most individuals. If certain individuals or teams regularly win and the others regularly lose (as does tend to happen), at some point those who continually lose, will stop making the effort Their performance will deteriorate instead of getting better. If there is only one winner and the rest lose, over time the majority of individuals will, thus, be losing and consequently will stop making the effort. The overall effect of using competition in the workplace, then, is that it will not motivate people to work harder, but will instead, tend to discourage people from trying (Daniels, 1989).

Competition can, however, be used advantageously in the work place with a slight shift in focus. If the competition is set up to be a competition against standards or goals, instead of a competition between individuals or teams, it can be a valuable tool Daniels, 1989). With this focus, it is possible for all of the workers who compete, to win. Winning or succeeding does tend to encourage people to continue to work hard, because winning or succeeding means that the efforts have paid off. Competing against standards can also have a bonus side effect. It frequently enhances cooperation between the individuals involved. One primary reason this may occur is that sometimes-greater success can be gained by working together.

Myth #4: The only way to motivate some people is to threaten them with the consequences

Threatening employees with job termination, loss of pay, reprimands or other undesirable consequences is a common tactic used to get some people to work. To the manager or supervisor who employs this tactic, it seems to be effective. This is because it usually results in the person doing whatever they need to do to avoid the consequence (Johnson, 1975; Komaki, (1986); Locke, Feren, McCaleb, Shaw, and Denny, 1980). This is especially true if the worker knows that the manager will follow through with what was said.

The worker doesn't do what is demanded and the consequences are delivered, over time the individual will either begin doing what he is told, or he will leave the company, by choice or through termination. Either situation, at first look, seems to be desirable. Either the work gets done or the problem employee is self-managed making room for someone who will possibly be a better worker.

There are, however, several problems with using threats in the workplace (Locke, et al, 1980). First, the threats may not work. Second, even if the threats work to get the desired performance, the employee is likely to perform only at the minimal level required and she may also become disgruntled. Third, if the threats lead to the employee leaving the company, there is a turnover cost that maybe significant.

If threats are stated, but not carried out, they will not be effective at getting the desired behavior. If employees learn that, despite what the manager says, they can continue to do just what they were doing without losing their job, or pay, or being reprimanded they will most likely just continue to do what they were doing. There really is no reason to change. In this case the threats clearly do not motivate the desired performance.

If the manager does use threats, does carry them out when necessary, and does, thereby, get the person to do what is being demanded, performance will still not be optimized and, additionally, several undesirable side effects may occur. Performance will not be maximized because the only benefit to the employee will be gained by doing just what was asked. In that way the threatened consequence may be avoided. Doing more than, or better than, what was demanded in the threat, won't result in any better outcome. Thus, the manager will get the performance that was required, but nothing more. In addition, employees who receive threats from their supervisors tend to become resentful and disgruntled. They may talk poorly about the manager, and perhaps the company, and they may look for opportunities to get back at either or both. Both of these situations could prove to be quite detrimental to the company.

If using threats leads to employees leaving the company, the company now has to deal with all the results of the turnover, including some work going undone f or some length of time, others having to pick up the slack, training new employees, etcetera. Because of the costs associated with turnover, it really is not desirable to lose many employees. Also in this scenario, the effort to motivate the employee to perform better clearly does not work.

An alternative to using threats and their consequences to try to motivate performance is to use a reverse strategy which is to acknowledge and reward employees for improving and for doing good work. This can lead to on-going improvement, in that, continual improvement continues to pay off for the employee. Thus, the manager can create an incentive for the employee to maximize performance instead of just getting by with what has to be done.

Myth #5: Managers should not have to use rewards to motivate people to do jobs they're getting paid to do.

Perhaps managers shouldn't have to use rewards to motivate people to work bard or do a good job. However, observations of work performance show that: 1) money is not enough to get all people to do what they are supposedly getting paid to do, and 2) rewards do work to motivate behavior (Connellan, 1978; Epstein, 1985; Johnson, 1975; Knapp, Hopper, and Bell, 1984). That is the reality. If money were enough to get people to do their jobs, there would be no problem. Furthermore, if rewarding and showing appreciation to people for doing good work does motivate people to perform better, it is logical to do so.

Myth #6: Companies cannot afford the cost of using rewards to motivate their employees

Rewarding employees for doing a good job does not have to be a costly venture (Daniels, 1994; Daniels, 1989). Small tokens of acknowledgement and appreciation that cost little or nothing can greatly enhance performance. How can this be? In most work settings such expressions of appreciation (praise) and acknowledgement of good performance (positive feedback) are so rare that their value is great. This is simply a matter of economics. What is in low supply (rewards) are in high demand People will pay more (in this case they will pay in teens of work output) for what is in high demand, but low supply (rewards). Sincere expressions of appreciation and acknowledgement can, thus, be rewards that cost the company little, yet bring large dividends in performance

Main #7: Managers cannot afford the time it takes to motivate employees with praise and reward systems

Many managers spend a large portion of their time "putting out fires". These problems arise, to a large extent, when the people they are supervising don't do what they are told to do. They do something else, or they don't do enough, or they don't do the job well. The common response to these problems is for the manager to repeat the instructions and/ or threaten with consequences to get the workers to do what they should have been doing in the first place (Daniels, 1989). If the task was unclear to begin with, repeating the instructions may or may not help depending on whether the manager is able to clarify what is desired If the initial instructions were clear, the employee not following them, is a motivational problem. If this is the case, as discussed above, using threats and punitive consequences, at best, just gets the job done to the minimum standard required. In contrast, using praise and reward systems can get employees to improve and work at levels far in excess of what is minimally acceptable. What this means is employees will do what they are praised and rewarded for doing. They will do what they are asked to do; as much or more than they are asked to do; and at or above the quality they are asked to do, if it benefits them to do so. By using praise and rewards to get people performing well, the manager is teeing proactive in problem-solving end will, in actuality save time. Metaphorically speaking, the manager will be able to "some forests" instead of just saving what can be saved by putting out the fires.

Myth #8: Some people are just plain lazy and if they don't have some self-motivation there's little, if anything, the manager can do to motivate them

Saying that some individuals are "lazy" is really saying that they are not motivated. If we look at motivation as a process of inciting action, instead of as an internal (static) state, we open the door to the possibility of being able to affect motivation (Daniels, 1994; Daniels, 1989). People who are 'self-motivated', thus, have developed the skill of being able to motivate themselves. Further, it is likely that they use the same tools to motivate their own behavior as are used to motivate the behavior of others. Part of what motivates their behavior is the fact that, doing what has to be done, helps them to avoid undesirable consequences such as failing, feeling guilty, and compounding stress. People who are highly self-motivated and do exceptionally well *(i.e.* those who maximize their performance), have experienced success, the acknowledgement of their success, and the excitement of their success. Many of these rewards have come from (and continue to come from external sources (parents, peers, teachers, supervisors, etc.), but what such self-motivated individuals have learned, is to also reward themselves. They have learned to recognize their successes, praise themselves for successes and allow themselves the good feelings that accompany their successes. People who are not self-motivated have not likely had similarly successful experiences and they have not acquired similar skills. Managers who work with such individuals are presented with a great opportunity to both motivate them and help them develop self-motivation skills.

If what develops motivation and self-motivation is 'success' as was argued above, then the first step in motivating and developing self-motivation is setting up individuals to succeed. This generally means setting goals and assigning tasks that will challenge the individual, but which also will be ones the individual will most likely be able to accomplish. As they succeed, the manager needs to point out the success, or help the individual identify their success, praise the success and show excitement over the success. Over time the individual will learn to experience these rewards aside from the input of others.

Is it cost effective for the manager to work on developing self-motivation in "lazy" employees? Perhaps "yes", perhaps "no" depending upon many factors, not the least of which is the cost of employee turnover. The point is, however, that even "lazy " employees can be motivated.

Conclusion

The paper presented has discussed several of the issues ant arguments centered on 'motivation'. The behavior analytic perspective has been presented in arguing against several commonly heft belief s about motivation in the work place. All of the ideas presented have been studied in various work place settings. The task at hand is to replicate and apply the steadies and findings within the construction industry.

There are some unique factors within the construction industry that may make some of the applications more challenging. For example, for some construction companies, each job means different work crews and, to some extent, different managers. This constant change can make it more difficult to apply appropriate rewards as motivators. Further, it may be even more tempting to use threats to motivate, since threats, as pointed out in the discussion, tends to work quickly and, thus, seem, at least in the short run, to be effective. With constant change in work groups, managers may not be as concerned with the long-term effects of using threats. However, given that many of the same workers will be employed on different jobs, and given concern for the quality of the present job, it is still in the best interest of the company to remember the potential harm in using threats to motivate workers.

Another factor that makes using reward systems a challenge is in dealing with unions. Legal, contractual, constraints can make the use of some reward systems all but impossible to implement. However, social rewards, such as praise, acknowledgement, and appreciation, because they don't involve monetary value, can usually be used without contention. Also, as pointed out above, because of the relative scarcity of praise and other verbal appreciation, if the comments are sincere, they can be highly motivating and can lead to enhanced self-motivation.

In the construction industry, as in any industry, there are limitations, or at least considerations, in applying motivational strategies. This is not, however, a reason to forgo methods that are more positive than some of the more traditional and more common, approaches. It is, instead a challenge to adapt strategies for the ultimate benefit of both the company and the employees.

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Journal of Construction Education
Summer 1997, Vol. 2, No. 2, pp. 99-108

1522-8150/97/$3.00/General Manuscript

Light-Gauge Steel Verses Conventional Wood Framing In Residential Construction

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This article examines light-gauge steel in residential construction with emphasis upon the economic differences and implications of its use as compared to conventional wood frame construction. Use of lumber for residential construction in the United States is influenced by several external factors. Increases in lumber prices directly affect residential market decisions. Environmental pressures to change the methods and public policy concerning timber harvesting have precipitated higher lumber prices and reduced the availability of the product. These market changes are causing developers, builders and architects to seriously consider alternate methods of construction. Two alternative forms of residential framing to conventional lumber construction are structures utilizing principally engineered lumber and light-gauge steel. Unfortunately, these systems also have their shortcomings. Residential construction can be done by simply substituting steel studs, which are manufactured in the same nominal widths and thickness, for wood studs in normal platform type construction. Although light-gauge steel has long been used in the commercial construction industry, principally for non-structural partition walls due to its fire-resistance; it has only recently become a serious alternative to lumber in residential construction. Steel framing is more commonly used in geographic locations that more frequently experience weather-related damage or natural disasters such as hurricanes and earthquakes. The many advantages of steel as compared to wood would indicate that steel has a very optimistic future in the near future, even if it should fall short of the predictions of market share that the steel industry anticipates.

Key Words: Residential Construction, Construction Framing, Building Materials, Steel Framing, Light-Gauge Steel

Introduction

The conventional use of lumber for residential construction in the United States is currently being influenced by two external factors that are causing developers, builders and architects to seriously consider alternative methods of construction. Several sharp increases in lumber prices in recent years and the continual fluctuation of such prices have been the most serious cause of this concern. The other factor, which some would argue has itself been reflected in increased lumber prices, has been environmental pressures to change the methods and public policy concerning timber harvesting.

The two most viable alternate forms of residential framing to conventional lumber are engineered lumber and light-gauge steel. These systems also have their shortcomings. For example, engineered lumber costs more than traditional milled lumber and has raised environmental concerns due to numerous chemicals used in its production. Also, steel has as its most significant shortfall the simple fact that it is a very good thermal conductor which means that it is a very poor insulator for the structures that are made from it.

The purpose of this article is to examine light gauge steel in residential construction with emphasis upon the economic differences and implications of its use as compared to conventional wood frame construction.

Traditional Use of Wood in Residential Construction

Wood has long been the material of choice in United States residential construction. Recently, wood has been questioned as the preferred framing material because of its gradually increasing and volatile prices in addition to concerns about decreasing quality and future availability (Yost, 1995).

The average single family detached home consumes some 11,000 board feet of lumber. The framing in such a house consists of joists, roof trusses plus exterior and interior walls which accounts for approximately 85% of the lumber used in construction of such a structure. The use of wood framing for residential construction constitutes some 60% of the U.S. softwood lumber consumption (Yost, 1995).

But according to Timm Locke of the Portland, Oregon-based Western Wood Products Association, stricter federal control over forestlands has caused a shift in available resources from old-growth timber to younger, smaller diameter trees. "Because we're using second-growth trees," explains Locke, "there's a decreased percentage of large members available. There's also a higher incidence of knots in the milled lumber." Higher demand and lower supply of suitable lumber have driven prices up (Barreneche, 1994).

Trends in Light Gauge Steel in Residential Construction

Although light-gauge steel has long been used in the commercial construction industry, principally for non-structural partition walls due to its fire-resistance; it has only recently become a serious alternative to lumber in residential construction. "Between 1979 and 1992 the number of steel framed homes increased more than 300 percent" (American Iron and Steel Institute (AISI), 1994). Yost (1995) cites a National Association of Home Builders (NAHB) survey that reveals that some 13,000 homes were built with light-gauge steel in 1993 which represents approximately 1% of the new homes built. This compares to only 500 steel framed homes a year earlier. The author assumes that the AISI figures demonstrate long-term growth in the inventory of steel frame homes while the NAHB statistics point out an explosive growth in new steel homes during a single year.

How significant is the trend toward steel frame residential construction. In an NAHB publication entitled Nations Building News it has been reported that a survey at the Pacific Coast Builders Conference in June 1995 showed three out of every four west coast builders, who have built with steel, are continuing to build with steel as a substitute for wood framing. A poll conducted at the

NAHB convention in January 1995 indicated that 22% of builders nationwide were planning to use light-gauge steel, while on a more regional basis, it was reported that 35% of west coast builders were planning to use steel.

More optimistically, Yost (1995) states that an estimate by the steel industry predicts 75,000 to 85,000 new steel framed homes will be built in 1995 and they also project 250,000 to 350,000 such homes to be built in the year 1997. This assumption, if realized, would represent 25% of new home starts at that time.

Currently, steel framing is more commonly used in geographic locations that more frequently experience weather-related damage or natural disasters such as hurricanes and earthquakes. Steel is used in such locations because it has higher tensile and greater bending strength than lumber thus it can better resist the destructive forces exerted upon residential structures during such occurrences. For these reasons steel framing has been employed more often in Florida, Texas (particularly Dallas), southern California, Hawaii, and the Pacific Northwest (Yost, 1995).

Light-Gauge Steel

Light-gauge steel is made by a cold-forming process where sheets of steel are passed through a series of roll forming dies to create there desired shade. The desired strength is achieved by a combination of the thickness or gauge of the steel utilized as well as the shape of the member. The various bends in the member's cross-section add to the stiffness and ultimate strength of the piece. Because of the strength advantage produced by this bending process, steel framing material has a strength-to-weight ratio that is very favorable when compared to most other materials, particularly wood (Waite, 1994).

The gauge or thickness of sheet steel ranges from 10 to 25. By convention the higher the gauge number the thinner the steel. The more lightweight non load-bearing interior walls of residential structures are usually made of 25-gauge steel, while the exterior load-bearing steel studs are usually built from stronger 18 or 20 gauge steel.

To protect steel from rusting, steel is zinc galvanized. This protection is necessary both during storage, construction and while in use to avoid damage and loss of strength due to rusting.

Weirton Steel Corporation (1995) advertises several advantages of light-gauge steel construction which are quoted below:

1. Steel components weigh 60% less than wood. A 2000 square foot home requires only 6 tons of steel compared to 20 tons of lumber.
2. No other construction material can match steel's superior strength and durability.
3. Steel construction components can be pre-measured and precut to exact specifications. On-site adjustments are generally not required.
4. Steel is simply impervious to termites and other damage-causing bugs and pests.
5. Steel stays straight and true, while wood may warp or crack.

6. Because steel is noncombustible and termite-proof, it qualifies for what insurance companies call -superior construction' and premiums are typically lower.
7. Steel components generate minimal waste and all light-gauge steel construction materials are 100% recyclable.

Other advantages or variations of the above are:

Steel has a consistent quality because it is a manufactured product and during construction there is not the 10-20% material waste that is typically experienced with wood framing operations (Yost, 1995). As previously discussed steel framing also has its own disadvantages that were best identified by Yost (1995) as follows:

1. Steel is an excellent thermal conductor requiring additional exterior insulation or thermal breaks to overcome this disadvantage. Thermal conductivity is probably the most serious of steel's disadvantages.

2. Because light-gauge steel frame construction is relatively new and innovative within the residential construction industry, it is not only unfamiliar to craftsmen but it is also unfamiliar to engineers and code officials.

   "Additional costly engineering analysis may be required. Residential building codes incorporating steel framing are currently under consideration but have not been implemented". The learning curve of builders and craftsmen may be slow until these individuals become familiar with the new skills required to construct with steel.

3. In addition to the labor training required to convert to the use of steel, builders and laborers must obtain some new tools not presently used by carpenters. The combination of additional training and tools translate to increased costs of construction for a short period of time.

Performance Problems of Steel Stud Wall Assemblies

It is well known that steel will conduct energy much better than wood and has very little thermal insulation value. This means that better exterior insulation is necessary to economically maintain the desired temperature of a home's interior during both cooling and heating seasons.

In Canada, the National Research Council's Institute for Research in Construction (IRC) has been researching the thermal characteristics of steel studs for years (Brown and Swartz, 1994). "The IRC research demonstrated that for the steel-stud wall assemblies ... , the R-value of the total assembly is approximately half that of the insulation. In other words, the presence of steel studs substantially reduces the overall performance of the whole assembly" (Brown and Stephenson+s study (as cited in Brown and Swartz, 1994)). Brown and Swartz also reference a report by Sasaki that said: " ... modifying the steel-stud web by introducing openings achieved improvements of up to 50% in thermal performance compared to conventional steel studs. By reducing the cross-sectional area of the steel web, the thermal performance of the wall assembly improved".

Brown and Swartz pose the question: "will insulation added to the outside face of the studs improve the thermal performance of the wall assembly?" They reply that it will improve thermal performance but they go on to state the IRC has found that although exterior insulation will contribute its R-value to the wall assembly, it will not remove the effect of the steel stud and there is the obvious economic cost of installing this exterior insulation.

The phenomenon known as "dust-marking" - a discoloration of the finished wall above the top of studs - is another thermal effect. Again insulation added to the exterior wall surface can help to reduce this problem (Brown and Swartz, 1994).

The results of IRC acoustical tests showed that non load-bearing steel stud walls performed approximately the same as wood studded walls. Surprisingly load-bearing steel stud walls performed better acoustically than wood stud walls (Brown and Swartz, 1994).

Brown and Swartz (1994) stated: "There is no particular evidence to suggest that steel-stud walls are more prone to moisture damage than wood-frame houses." They go on to point out "moisture in the wall assembly can cause their corrosion (just as it causes rotting of studs in wood-frame construction). The control of moisture can be undermined in many ways — poor design, poor construction practices, or a combination of both."

Types of Construction

Residential construction can be done by simply substituting steel studs that are manufactured in the same nominal widths and thickness for wood studs in normal platform type construction.

Efficient structures can also be designed that utilize the superior strength of steel by increasing the stud spacing to four feet or more (Waite, 1994).

Nearly all building systems to include light-gauge steel employ standard size structural members that have evolved over time based upon conventional lumber dimensions. The rational has been to be able to use existing components such as prefabricated door and window units thus avoiding the necessity of having door and window units custom fabricated. Consequently light-gauge steel members are the same size as wood frame structural members, such as nominal 2+ thicknesses with nominal 4+, 6+, 8+ and etc. widths and lengths in typical 2 foot lengths. Similarly, the sheathing and interior wallboard systems are based upon the use of standard 4+ x 8+ panels.

The three basic light-gauge steel assembly methods are stick-built construction, panelized systems, and pre-engineered systems. The American Iron and Steel Institute (1994) best describes these three methods as follows:

Stick-Built Construction

Stick-built construction is virtually the same in wood and steel. This framing method has actually gone through a transformation incorporating many of the techniques used in panelized construction. The steel materials are delivered to the job-site in stock lengths or in some cases cut to length. The layout and assembly of steel framing is the same as for lumber, except components are screwed together rather than nailed. Steel joists can be ordered in long lengths to span the full width of the home. This expedites the framing process and eliminates lap joints. Sheathing and finish materials are fastened with screws or pneumatic pins.

Panelized Systems

Panelization consists of a system for pre-fabricating walls, floors and/or roof components into sections. This method of construction is most efficient where there is a repetition of panel types and dimensions. Panels can be made in the shop or in the field. A jig is developed for each type of panel. Steel studs and joists are ordered cut-to-length for most panel work, placed into the jig and fastened either by screws or welding. The exterior sheathing, or in some cases, the complete exterior finish, is applied to the panel prior to erection.

Shop panelization can offer several significant advantages to the builder. The panel shop provides a controlled environment where work can proceed regardless of weather conditions. Application of sheathing and finish systems is easier and faster with the panels in a horizontal position. Although the panels must be transported from the panel shop to the job, most often the cost advantages of panelization offset the added transportation costs.

A major benefit of panelization is the speed of erection. A job can usually be framed in about one quarter of the time required to stick-build. When you consider that the exterior finish system may also be part of the panel, the overall time saving may be even greater.

Pre-Engineered Systems

Because of steel's high strength and design flexibility, innovative systems are possible which are not possible using other materials. Engineered systems typically space the primary load carrying members more than 24 inches on center, sometimes up to 8 feet. These systems use either secondary horizontal members to distribute wind loads to the columns or lighter weight steel in-fill studs between columns. Furring channels used to support sheathing materials also provide a break in the heat flow path to the exterior, which increases thermal efficiency.

Many of the pre-engineered systems provide framing members that are pre-cut to length with pre-drilled holes for bolts or screws. Most of the fabrication labor is done by supplier, allowing a home in as little as one day.

Development of Prescriptive Standards

Currently, there are no accepted standards for residential light-gauge steel design that may be adopted by building code officials. This situation places light-gauge steel construction at a slight disadvantage to wood frame residential construction that has had accepted prescriptive standards for some time. The disadvantage of not having prescriptive standards for residential steel frame construction is that for a builder to have a home approved by the building code officials, a qualified engineer this adds to the cost of completed structure must approve the design.

The cost of having engineering analysis performed for a light-gauge steel home can increase the cost of construction from $.75 to $1.50 per square foot according to Bill Farkas, research engineer at the National Association of Home Builders Research Center. Farkas explains the above situation arises because steel is relatively new in residential construction and no standardized tables exist for the building codes. He goes further to state "Once a specific home design 'is approved and stamped,' however, it can be reused without further analysis" (Ryan, 1995).

Why is the development of an industry standard for light-gauge steel so difficult? First, the North American manufacturers who produce raw steel utilize several established quality codes. Thus the steel that finds its way into light-gauge metal studs is not standardized. Next, the cold-formed steel companies produce numerous products, all of which must meet the standards and guidelines of the ASTM (American Society of Testing and Materials) but again nothing is standardized as to the size and shape of the product produced. The result is that the shapes and sizes of light-gauge steel vary significantly from one producer to another making the development of a prescriptive design standard extremely difficult. Consequently, "an engineered design is usually required to build a home with steel as load bearing members" (Waite, 1995).

How may this obstacle be overcome? Through the coordinated efforts of the U.S. Department of Housing and Urban Development (HUD), National Association of Home Builders (NAHB), and the American Iron and Steel Institute (AISI) "a steering committee of industry experts, including code officials, engineers, researches, manufacturers and builders was assembled to assist in planning and directing" the development of a code change to the Council of American Building Officials (CABO) One and Two-Family Dwelling Code, according to Jay Crandell, project manager for the NAHB Research Center (Building Code to Include ... , 1995).

Crandell goes on to emphasis that "Prescriptive construction guidelines is also a key element of the new residential building code since it provides a 'cookbook' approach to light-gauge steel framing." "Giving builders clear information on what designs, types of materials and construction techniques comply with the codes will drastically ease the process of building a steel-frame house," said Crandell. (Building Code to Include ..., 1995).

The NAHB has the lead and responsibility of coordinating the efforts of the other participants in development of this prescriptive standard.

Within the AISI, a taskgroup within the Codes and Standards Subcommittee has been formed that is developing industry standards and labeling requirements. These standards will be incorporated into the "NAHB's prescriptive standard work that will be finalized this fall" (Meyers, 1995).

Meyers (1995) states that the AISI will complete their light-gauge steel standards development by the fall of 1995 that "will preserve the integrity of our product, insure a cost-effective position, respect the business interests of all cold form applications, and increase the user friendliness of the product".

It is noted by Meyers (1995) that the steel fastener industry has made a significant impact upon the development of a prescriptive standard through their effort in new product development. He cites Erico Tool and Fasteners for their development of a new fastener to attach foam insulation to steel framing and ITW Paslode's new fastener attachment for wood sheathing.

Cost Comparison Between Wood and Light Gauge Steel

When comparing the cost of residential construction with wood versus light-gauge steel, the factors that must be considered are: price of materials, labor costs and design flexibility. The price of dimensional lumber has gradually increased over the last few years with large price fluctuations while steel by comparison has gradually declined in price due to increased capacity of steel smelting and hot-rolled sheet production plus steel industry increases in galvanizing capacity. Additionally, the price fluctuation of steel has been less dramatic than that of wood (Yost, 1995). The combined impact of these factors, states Yost (1995), is that "steel-framing costs are at least comparable to and possibly lower than for lumber framing" (as cited from Bauer, 1992).

A California builder has obtained a 12% cost savings of steel versus wood construction by using an engineered design for steel framing rather than a simple one-for-one structural member substitution. This translates to a $1200 to $1500 cost reduction per home (Yost, 1995 who referenced McLeister, 1993).

Yost (1995) goes on to reference an article from Building Systems Builder that cost savings for steel framing material can range from 30 to 59% for wall studs and up to 25% for steel floor joists.

Steel framing cost savings can be as high as 30% when compared to the price of wood, claims Irv Hughes of Columbus, Ohio. Hughes is a local builder and Vice-President of the Building Industry Association of Licking County (Peck, 1994).

Wolcott (1995) states "In 1993 and 1994, lumber prices varied from $310 to $500 per thousand board feet. Both timber and industry officials agree that steel becomes a competitive substitute when wood prices range between $350 and $400 per thousand board feet."

The NAHB Research Center with funding from HUD conducted three case studies comparing three residential construction systems to conventional building wood frame construction. Steel frame construction was observed and the Group-Timing Technique was used to gather data for

23 homes built as part of phase II of the Sunset Ridge Limited development in Imperial, California. During the framing of the 25 homes in phase I the framers became experienced in the use of the use of light-gauge steel framing methods. The steel framed homes studied all had slab-on-grade foundations and ranged in size from 1,175 to 1,940 square feet. Similar observations were made of comparable conventional wood frame construction (Waite, 1994).

The results as reported by Waite (1994) were:

> "The material costs for the light-gauge steel walls were 2 percent less than for the conventional wood walls, while the total costs for the light-gauge steel walls were 7 percent more than the walls in the conventional wood-framed house."

Conclusion

Based upon the information available at his time it is probably debatable that light-gauge steel framing is cheaper than conventional wood frame construction. Many of the statements in the literature concerning the economics of light-gauge steel frame construction as compared to lumber appear to be measuring the two differently. When one says, "steel framing is cheaper than wood framing", is one saying that engineered light-gauge steel framing (24 inches on center (o.c.) or greater) is cheaper than non-engineered conventional wood framing (16 inches o.c.)? Unfortunately, many of the light-gauge steel articles available today are published in trade journals with more of a marketing perspective than literary journals that explain the scientific methods utilized to develop their stated results or position. The body of literature on this subject, beyond comparing steel framing to wood framing, does not begin to address the economic impact of additional building systems within the initial purchase price of a residence. It appears that some residential sub-contractors that perform activities after the framing is complete are charging more for their work in steel framed residences than in wood framed residences. Whether or not these additional costs are justified is possibly debatable, but if additional charges are being made, the resulting increase on the sales price of the home has an impact on the economic acceptance of light-gauge steel framing by future homebuyers.

The many advantages of steel as compared to wood would seem to indicate that steel has a very optimistic outlook in the near future, even if it should fall short of the predictions of market share that the steel industry anticipates.

During the writing of this literature review on light-gauge steel framing, several unanswered questions came to mind:

1. What are the square foot framing costs of identical homes of engineered light-gauge steel and conventional wood frame construction?
2. What is the average square foot cost to complete construction to the same standard for the two framing systems described in the above question? A subset of questions within the previous question is what are average cost factors, charged by the many sub-contractors who follow the steel framers, above and beyond what they normally charge for comparable work within conventional wood framed homes?

3. How time and cost effective are the new pneumatic nail guns that are being developed to replace manually fed screw guns? How effective are the nails/fasteners from these pneumatic nail guns when placed in withdrawal versus shear?
4. How cost effective would it be to panelize large light-gauge steel exterior wall sections and roof trusses on an assembly line, transport them to the building site and erect them with reasonably light weight material handling equipment utilizing small crews of workman?

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Journal of Construction Education
Summer 1997, Vol. 2, No. 2, pp. 109-118

1522-8150/97/$3.00/General Manuscript

Subsurface Utility Engineering: An Initial Step in Project Development

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The accurate location of underground structures is a serious problem in construction. Subsurface Utility Engineering (SUE) is an emerging solution to this subsurface structures problem. SUE is a process that incorporates new and existing technologies to accurately locate underground facilities during early development of a project. This paper discusses the current locating practices and the benefits that can be obtained through the application of SUE. It will be evident that SUE can reduce unexpected utility conflicts, construction delays, contractor claims, utility relocations, project redesigns, and the time required to design projects. In summary, when the SUE process is applied, contractors' risk is reduced, and a cost savings of $7-$10, or possibly $15, for every $1 spent on SUE is realized.

Key Words: Subsurface Utility Engineering (SUE), Quality Levels "A," "B," "C," and "D," Designating and Locating, Surface Geophysical Methods, Subsurface Utility Characterization, Utility Location Disclaimer Note

Introduction

The development of a typical construction project involves the phases of planning, design, and construction. Typical underground-structure damage-prevention practices are currently applied during the construction phase of the project. Every state currently has some sort of a one-call system that function during this construction phase. Unfortunately for contractors, the application of typical underground-structure damage-prevention practices during the construction phase does little to reduce the risk of hitting an underground structure. A better solution to the subsurface structures problem would be to place emphasis on the design phase of the project, and to engineer risk out of the project.

Background

Costs Incurred

Contractors' risk is usually compounded by the low-bid contracting procedures currently used by most project owners. Not included among the bid costs are the extra costs for the problems created by the incorrectly shown, omitted, or unknown locations of underground structures. Often, the owner and contractor seek arbitration or even litigation due to these problems created by the incorrectly shown, omitted, or unknown locations of underground structures. Interference with utility lines, communication cables, tanks, and old foundations are only a few of the examples of the results caused by misinformation or lack of information, further increasing the cost of construction projects. Traditionally, the contractor has been forced to be at risk for the location of the subsurface structures. However, the courts are beginning to recognize that contractors are being unfairly placed at risk, and in recent cases, have placed the responsibility for showing the correct locations of utilities onto the owners.

Lack of incentive causes deaths

The traditional approach to many projects where the owner is funded by the taxpayer or ratepayer is to pass the cost of doing business to the general public. These types of projects have little or no incentive to employ, let alone use, strategies that will reduce the project's costs. Tragically, these costs are sometimes the lives of construction workers, or the general public in the form of an innocent bystander killed in a gas-line explosion. The chances of property loss, injury, and even death are real in construction due to the obvious danger involved when striking gas or high-pressure petroleum lines. These dangers and the resulting incidents are more real than most people are aware. Bernold (1994) reported that excavating equipment hitting buried utility lines causes an average of one death per day in the United States.

Project delays and costs

Other underground risks are not so obvious. Project delays and cost increases happen due to conflicts with existing utilities and structures that are uncovered during construction operations. Of course, these conflicts become the source of change orders to the scope of the project, and claims for delays. These conflicts set back the revenues derived from income-producing projects and commercial developments. A simple reason for these risks and resulting conflicts is existing records used by the owners and their engineers are not sufficient enough in detail or complete enough for design purposes.

Existing Records of Owner's Underground Structures

A brief overview of the status of underground structures records is appropriate to describe the nature of the subsurface structures problem facing the construction industry. The design of a project is normally based on existing records that frequently are incorrect, incomplete, out of date, or inadequate for actual design and construction purposes. There may be many reasons why this is true. Some are listed as follows:

Working drawings were not accurate in the first place, or the design drawings were used for record keeping.

Some as-builts may be correct, but others are not correct due to human error during the record keeping.

No as-builts or record drawings were ever made.

The records created by multiple utility owners at the same site, who have been installing underground structures for decades, have never been placed in a single central file, or are lost, or are incomplete.

> The references on the record drawings are lost and cannot be recreated. For example, a reference might specify a certain distance to a building that is no longer there.

Traditional Design Practices

The designers of construction projects understand the nature of incomplete subsurface records, and they attempt to protect themselves and limit their liability by including a disclaimer on the project's plans. The wording of this disclaimer varies, but a typical paraphrasing is as follows:

> The utilities shown on these plans were taken from the records of utility companies. The actual location of utility lines and other features may be different. It is the responsibility of the contractor to identify, verify, and safely locate all utilities and features for this project at the time of construction.

Designers make little or no effort to field-locate utilities and underground features during the design process. At best, they rely on past experience in an area. Information on the project's plans is left at the risk of the contractor. During the design phase, utility owners mark their locations under one-call procedures. When conflict problems arise during construction, the question of whether or not the mark was correct arises, and there is usually insufficient evidence to assign location responsibility.

Tradition and past practices have caused an assumption that there will always be problems with underground conflicts, especially with utilities. An accepted belief is that the conflicts are inevitable and the resulting change orders cannot be avoided. For this reason, project owners have had little incentive to require designers to do a better job of locating.

Quality Levels

For a designer or constructor to understand the concept of SUE, it is first necessary to comprehend the quality levels established for subsurface information used for locating underground structures. The normally accepted definitions are as follows:

> *Quality Level "D"*. Quality Level "D" (or QL "D") is the most basic level of subsurface locating information. All QL "D" information is derived from a review of available existing records and utility as-built records. The application of this level is for planning purposes such as route selection and utility relocation costs. Quality level "D" information does provide one with the overall concept of potential underground structure location, but, for design purposes, is limited in terms of the detail, accuracy, and comprehensiveness required to eliminate the risks and dangers of conflict with underground structures.

> *Quality Level "C"*. Quality Level "C" (or QL "C") information is the most common type used for design purposes. This level involves adding to and adjusting Quality Level "D" as-built information with an above-ground inventory of all visible features and evidences of utilities or foundations. Level "C" information is still not accurate enough to prevent

conflicts. Studies have shown that with accepted tolerance standards of two feet or less, there is still a 15 to 30 percent error and omission rate.

Quality Level "B". Quality Level "B" (or QL "B") involves the actual use of technology that supplements Quality Level "D," as-built information, with "designating." Designating requires the use of surface geophysical techniques and methods to determine the existence and horizontal location in two dimensions of underground structures and utility features. This designating, or horizontal mapping information, permits sound decisions to be made during the design phase of a project on the placement of foundation footings, drainage systems, and any subsurface feature that conflicts with existing utilities and underground structures. Adjustments in design and layout can be made that yield cost savings by eliminating utility line relocations and moving the excavation work away from existing utilities and underground features. Information in this level should not be used for vertical design basis or when close or minimum horizontal tolerances are required.

Quality level "A". Quality level "A" (or QL "A") represents the highest accuracy level of presenting subsurface features by adding actual "locating" to Quality Level "B" information. Information can now be mapped horizontally and vertically in three dimensions. Locations are determined by nondestructive excavation methods at critical conflict points to expose the underground features. Exact determinations of horizontal and vertical positions are now made in three dimensions. The resulting highly accurate information is used to design the project to avoid most underground conflicts, thus avoiding utility line relocation or nearby excavation, providing condition assessment, construction, and maintenance information.

Subsurface Utility Engineering (SUE)

Subsurface Utility Engineering (SUE) is a newly developed engineering process that incorporates new and existing technologies to accurately identify and map underground facilities during the early development and design stages of a project. The main components of SUE are:

Designation - the use of geophysical investigating techniques and methods (as indicated in Table 1) to determine the existence and horizontal position of underground utilities and structures. A designation may indicate the existence of two or more utility lines, thus requiring location to determine exactly what is there. It is necessary to proceed to the location step to make this determination.

Location - the use of nondestructive digging equipment at critical points along a subsurface project's path or location to determine the exact and precise horizontal and vertical position of buried utilities and other subsurface objects.

Data Management - the use of the above designation and location information by designers and engineers for examining project options and for planning ahead to eliminate conflicts before they occur. The information can be obtained by surface geophysical surveys and then entering the information into a computer-based data management system.

Though many of the technology techniques and methods already exist for locating underground structures, until now there has been no one process to ensure that accurate, in-depth, and complete information can be available prior to bid time. Applying this invaluable preliminary tool known as SUE during the design phase of a project will generate benefits (costs, timeliness, and safety) for both the owner and the contractor. The designers can then feel confident about the accuracy of the subsurface information on the plans they provide.

Geophysical Methods Used for Locating Subsurface Features

Many surface geophysical methods and equipment are available to the SUE practitioner to locate underground features. Traditional methods used by utility owners are to mark locations for contractors at the time of construction. These methods will remain in use, however, they do not provide sufficient damage prevention. The geophysical methods shown in Table 1 should be employed with Subsurface Utility Engineering.

Table 1

Surface geophysical methods available for subsurface feature locations

Title of Method	Description of Method
Radiofrequency Electromagnetics ELF, VLF, LF ranges	Inexpensive and highly useful for metallic lines, or accessible utilities that can have conductors or transmitters inserted into them.
Magnetics - Flux gate	Inexpensive and most useful for utility lines and appurtenances that exhibit a strong magnetic field at ground surface.
Elastic wave introduction into a non-compressible fluid	Inexpensive and moderately useful for water lines with sufficient access points (typically fire hydrants) and low ambient noise.
Terrain Conductivity	Moderately inexpensive and useful in non-utility congested areas, or areas of high ambient conductivity. Most useful in the detection of tanks and drums.
Impulse Radar (Ground Penetrating Radar)	Moderately expensive and highly interpretative. Useless in areas of high conductivity such as marine clays, or for small targets such as small diameter lines.
Seismic Reflection and Refraction	Expensive and highly interpretative. Its usefulness under field conditions is extremely limited due to signal/noise ratio problems.
Thermal Imagery	Moderately expensive and interpretative. It is sometimes useful for poorly insulated steam systems or other high heat-flux systems.
Radioisotope Tracing	Moderately inexpensive to highly expensive. Useful for utilities already impregnated with radioactive isotopes.
Microgravitational	Expensive. This method is limited to identifying utilities of large differential in mass from their surrounding environment.

(Source: Anspach, J. H., Proceedings of the American Society of Civil Engineers 1995 Conference)

Costs and Benefits of SUE

To understand the cost reduction potential of SUE, one must be aware of the costs and benefits. On projects where SUE is used, its cost is typically 10 percent of the total preliminary engineering costs. This translates to approximately 1 percent of the total project cost. The benefits are several.

Costs

The cost of obtaining information at the Quality “A” Level for mapping, surveying, designating, and locating can vary in a range from a high of $1000 per test hole to a low of $300 per test hole. The range difference is due to the degree of difficulty involved depending on the type of surface penetrated and the nature of the site soil conditions. The cost of Quality Level B information, mapping, surveying, and designating, is less than Quality Level A. As a general rule, designating information costs approximately $1 per linear foot of underground structure feature. For example, a building site with 1,500 feet of underground utility lines, a 20-foot buried tank, and 300 feet of adjacent foundations would generally have less than $2,000 in designation cost.

Benefits

SUE reduces utility line relocations, unexpected utility conflicts, cut utility lines, conflicts with abandoned buried tanks, and increases the accuracy of environmental site assessment. These benefits combined with subsequent reduction in bid prices, reduction of construction delays, reduced contractor claims, and lower redesign costs may result in a savings of fifteen dollars for every one dollar spent on SUE for a typical project. Several documented examples of the benefits achieved from using SUE are presented as follows:

> On a major highway project in Richmond, VA, the SUE provider for the Virginia Department of Transportation (VDOT) dug 156 test holes at locations where Quality Level B information indicated highway/utility conflicts. Using this newly obtained Quality Level A information, VDOT’s roadway and hydraulic engineering designers were able to determine that conflicts would occur at 75 of the sites. As a result, design revisions and changes were made, and 61 of the potential conflicts were eliminated. Making these design changes avoided $731,425 worth of utility adjustments. The cost of excavating the test holes was only $93,553, resulting in a savings of $637,872.
>
> Columbus Southern Power Company employed SUE during the design phase of a 138KV electric underground duct 1.2 miles long through downtown Columbus, Ohio. The cost of SUE totaled slightly less than $100,000. After interviewing the successful bidder for construction of the electric duct, it was determined that the bid price had been reduced by $400,000 due to the accuracy and completeness of the underground utility information. In addition, there were no utility relocations, no contractor claims, no utility damages, and no change orders during the project. Lastly, the project was completed ahead of schedule.
>
> The Federal Highway Administration (FHWA) sponsored research on SUE, and has experience with the application of SUE on its projects. Based on its research and experience, the FHWA estimates that the proper use of SUE could result in nationwide cost savings exceeding $100,000,000 per year for highway work alone.

Permit requirements for a new cogeneration facility in Bayonne, New Jersey, included an environmental assessment of the site which was an old industrial location. SUE techniques were used as a part of the environmental site assessment to fully identify, characterize, and map all existing utilities with a high degree of accuracy. SUE was then employed to conduct a site geophysical survey as part of the environmental site investigation. A total of 37 significant inconsistencies in the subsurface conditions were documented. Investigation of the inconsistencies proved that almost all were environmentally harmless as a result of differing compositions of fill that had been used at the site over the years. Based on the complete site environmental characterization as supplemented by SUE, the environmental permit was approved on first submittal. A significant reduction in scheduled construction time could then be achieved.

The advantages of SUE extend beyond those of decreasing the risks of conflicts, and decreasing the compromising of utility lines as a result of construction. Significant cost savings result to the taxpayer, the ratepayer, and the owner on projects that employ SUE. Stevens (1993) approximated the basic categories of project expenditures in Table 2.

Table 2

Basic categories of project expenditures

Category	**Cost**
Administrative Costs	20%
Engineering Costs	10%
Construction Costs	45%
Cost "Overruns"	15%
Utility Relocation Costs	10%

When compared to projects not utilizing SUE, a total cost savings of 10% to 15% on a typical project can be realized as reported by Stevens (1994). The cost savings may be realized in several forms, which Stevens (1994) approximates below:

Administrative savings of 1/10th of 20% yield a 2% project savings. Projects will be completed up to 20% faster according to the Virginia Transportation Study, which allows for faster progress payments and reduces the project's financing costs.

Engineering savings of 1/20th of 10% yield a 1/2% project savings. By employing digital transfer of survey data into CADD files, and by having conflicts with underground structures resolved by SUE techniques, results occur in design savings.

Construction cost savings of 1/20th of 45% yield a 2.25% project savings. Bids for construction are reduced due to fewer conflicts with underground structures and the increased confidence in having correct information on the project's plans. A critical point is that the liability for identification of utilities is borne by the SUE company, not by the constructor.

Cost Overrun savings are 1/3 of 15%, or 5%. This is a significant savings resulting from reducing contractor delay claims, engineering rework, and utility cut damages.

Utility Relocation Costs realize savings of 1/2 of 10%, or 5%, which again, reflects a significant cost savings resulting from designers accepting the accurate, complete, utility information as part of the design process throughout the design phase. Large scale utility relocations before construction can start are eliminated by minor design changes.

Conclusion

There is increasing congestion of utilities and other underground structures in today's urban areas, military bases, and industrial locations. This congestion increases the need for complete and accurate utility and underground structure location information in the best interest of the general public and private facility owners.

The need for rebuilding and upgrading existing facilities and infrastructure continues to grow throughout the nation. Cost effective SUE techniques and technology need to be employed in the development and design of these projects to obtain the most for the construction dollar. With SUE's techniques and technology for locating subsurface utilities, SUE can be used to locate features under built floors and behind walls in building refurbishing projects. Several owner studies indicate that cost savings, typically around $10 for each $1 spent for SUE services, can be achieved for most projects. SUE is proven technology in this area.

An increasing number of projects are now being designed with better subsurface information on the existing underground structures located within the project's site. The contractor benefits from better subsurface information records on the condition of utilities. The contractor can then, before construction begins, make proper, safe excavation protection and utility line protection systems choices. The result is a safer more economical excavation project.

Recommendations

Develop a national consensus or regulatory standard for the depiction of utility information on construction documents, including methods to obtain the information.

1. Issue permits through public agencies for public occupancy work or work in the public right-of-way for work to be completed with an underground damage prevention plan sealed by the proper professional showing the quality level of the underground features shown on the plans.

2. Require the use of the Subsurface Utility Engineering process on all projects that are publicly funded where underground features may be encountered.

3. Institute a program to update existing plan underground information on public facilities to a quality level of at least "B."

4. Develop procedures to change the standard disclaimer statement on drawings to one that clearly addresses the responsibility for the location of underground features.

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Journal of Construction Education
Summer 1997, Vol. 2, No. 2, pp. 119-132

1522-8150/97/$3.00/General Manuscript

Statutes of Repose: Protection for Manufacturers and Material Suppliers

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Most states have adopted Statutes of Repose to protect architects, engineers and constructors of improvements to real property from lawsuits arising after a specific number of years after completion of an improvement to real property. These Statutes of Repose differ from Statues of Limitation in that a statute of repose can bar claims before they have arisen, while a statute of limitation bars claims after they have arisen. The extent to which a statute of repose protects manufacturers and material suppliers varies greatly among the states. State courts have developed two theories to determine if a particular manufacturer or material provider is protected: the improvement analysis and the activity analysis. The activity analysis is superior. The improvement analysis extends protection to products that are defined as "improvements" but not to products that might be component parts or material. The activity analysis extends protection to those entities that incorporate their products into the real property. All states should adopt an activity analysis. All states should extend the protection of the statute of repose to entities which install their product into/onto real property improvements or who custom-make or design products for installation into/onto real property improvements.

Key Words: Repose, Activity Analysis, Improvement Analysis, Limitations of Actions

Introduction

This paper is an overview of the extent state statutes of repose protects manufacturers and material suppliers to the construction industry from injury claims. This paper cannot be taken as legal advice on the law in any particular state and should the reader have a specific legal problem in any way similar to any matter discussed herein, the reader should consult an attorney.

Thirty-eight states presently have enforceable Statutes of Repose to limit the liability of architects, engineers and contractors for all injury claims, including product liability claims arising out of construction projects. See Appendix A for a list of each states statute, if any, and whether or not is has withstood constitutional attack. If the court has not upheld the constitutionality of a statute, the statute has no force or effect in the state. As a general rule, statutes of repose apply ONLY to the construction industry, however, New York statutes of repose are not specifically aimed at the construction industry. Some states, for example, North Carolina and Colorado have statutes of repose for general product liability claims, and many states are also looking into passing similar statutes to limit product liability claims.

A statute of repose differs from a statue of limitation. A statute of repose can bar claims before they have arisen, while a statute of limitation can only bar claims after they have arisen.

The extent to which statutes of repose protect manufacturers and material suppliers from claims varies widely depending on the state where the construction project is located. It is important for manufacturers of products to know to what extent they are protected from liability for lawsuits under these statutes. In some states heavy equipment installed in or on real property may be protected to the same extent that buildings and structures are.

In any lawsuit involving any type of material or product and construction, the parties should carefully review the applicable statute of repose and the case law to determine if the suit is barred. If a material provider or manufacturer can obtain protection under the statute of repose, the case against it will be dismissed. However, the states vary widely on the extent of protection afforded manufacturers and material providers and the law is not settled in each jurisdiction. Knowledge of how other states handle these types of lawsuits might be used to convince a court to extend or deny protection of the statute to a particular manufacturer or material provider.

Statutes of Repose vs. Statutes of Limitation

Forty-eight states have enacted statutes of repose to limit the liability of architects, engineers and contractors for claims arising out of construction projects. Eleven state courts have invalidated the statute on various state constitutional grounds. For example Kentucky held the five-year statute of repose violated the special legislation clause of its constitution. (*Tabler v. Wallace*, 704 S.W.2d 179 (Ky. 1985), cert.denied 479 U.S. 822, 107 S. Ct. 89, 93 L.Ed. 2d 41 (1986) South Carolina held its Statute to violate equal protection in *Broome v. Truluck*, 270 S.C. 227, 241 S.E.2d 739 (S.C. 1978).

Alaska has recently passed another statute of repose that has not yet been constitutionally tested. Other states may do the same. See Appendix A for a detailed list of state statutes of repose. The District of Columbia is also included.

Statutes of Repose prevent injured parties from recovering for damages suffered as the result of defective and/or unsafe conditions in an improvement to real property. The statutes prevent contractors from being sued. If a lawsuit is filed after the period provided in the law, it is relatively inexpensive for the contractor to have it dismissed without the need for expensive litigation and certainly, a trial will be avoided. The lengths of the statutes vary from five years (Ark. Stat. 16-56-112 (1987) Va. Code @ 8.01-250 (1995) to twenty years (Md. Cts. & Jud. Proc. Code @ 5-108 (Supp. 1991).

Some states refer to Statutes of Repose as "Statutes of Limitation". For example the California court in *Regents of University of Cal. v. Hartford Acci. & Indem. Co.*, (1978) 21 C.3d 624, 147 Cal.Rptr 486, 581 P.2d 197 said, "Code Civ. Proc., @ 337.15 is an ordinary procedural statute of limitations, subject to the same rules as other statutes of limitations". Other states have other names for the same type of statute. See Code of Ala. @ 6-5-218 (1994) which calls the statute a "Rule of Prescription".

A Texas court said in reference to Texas Civ. Prac. & Rem. Code "16.009 is not a statute of limitation, but rather an ultimate statute of repose that bars all claims after the prescribed 10-year period." *Tumminello v. U.S. Home Corp.* 801 S.W.2d 186 (Tex.App.-Houston 1990).

In this article "statute of repose" shall refer to any state statute which limits the period of filing a lawsuit from some event OTHER than an injury. In the case of Statutes of Repose the event is generally the completion or substantial completion of an improvement to real property. A typical statute of repose will allow lawsuits to be filed against constructors, architects, and engineers only up to a certain date after completion of the construction project. After the particular date all lawsuits are barred.

To fully understand a statute of repose it is necessary to compare it with a statute of limitations. For example, a typical statute of limitations requires suits for personal injuries be filed within two years of the date of injury. A lawsuit, for an injury, which occurs fifty years after the completion of a building, could still be filed against the architect, engineer or constructor, as long as the lawsuit is filed within two years of the date of injury. Statutes of Repose have been enacted to prevent just this type of lawsuit.

Statutes of Repose therefore can bar claims before they have arisen, while Statutes of Limitations can only bar claims sometime after they have arisen. The graph below illustrates the interaction between a two-year Statute of Limitation and an eight-year statute of repose.

Table 1

Statute of Repose compared to Statute of Limitation

Year 0	**Year 2**	**Year 4**		**Year 6**	**Year 8**
Construct. Completed	Claim #1 arises	*Claim #1 must be filed or barred by 2 year Statute of Limitations*	Year 7 arises	Claim #3	Claim #2 arises, but is barred by 8 year Statute of Repose

Claim #1 involves an injury that occurs in Year 2 after completion of construction. The injured party has two years, or until Year #4, to file a lawsuit. Claim #2 arises against the contractor eight years PLUS after completion of construction. Claim #2 is barred by the statute of repose, and was barred even before the claim arose. All claims against the contractor, architect, and engineer are barred after the eight anniversary of the construction project. The contractor can fairly easily have the claim dismissed.

Many, but not all Statutes of Repose extend the period to sue to that of the Statute of Limitations, if the claim arises prior to the statute of repose cut-off date. For example Claim #3 above, which arises seven years after completion, could be filed up until year nine in many states.

The Texas ten-year statute of repose is one such statute. The claimant has two years to file suit if injury occurs within ten years of completion of the project. California however does not extend protection, and a claim that arises on the last day of the running of the statute of repose will fail unless filed the next day. See *Liptak v Diane Apartments, Inc.*, (1980) 109 C.A.3d 762, 167 Cal.Rptr 440.

Contractors should therefore realize statutes of limitation provide a time frame after a claim arises during which they can be sued. Statutes of Repose provide a time frame after completion of a project during which the contractor can be sued. Once that period expires the contractor cannot be held liable for any injuries caused by the construction – all risk of injury passes to the owner.

Types of Entities Protected by Statutes of Repose

A comparison of statutes of repose across state lines reveals they protect architects, engineers and persons who construct real property improvements. However, a great difference has developed in the extent to which the state's statute of repose protects material suppliers and manufacturers who provide products incorporated in or attached to the real property.

North Carolina's statute specifically protects material providers, N.C. Gen. Stat. @ 1-50 (1994):

> "(5) a. No action to recover damages based upon or arising out of the defective or unsafe condition of an improvement to real property shall be brought more than six years from the later of the specific last act or omission of the defendant giving rise to the cause of action or substantial completion of the improvement.
>
> b. For purposes of this subdivision, an action based upon or arising out of the defective or unsafe condition of an improvement to real property includes:
>
> 9. Actions against any person furnishing materials..." (emphasis added)

North Carolina statutes also protect manufacturers from product liability claims. This protection is not limited to the construction industry.(See *Lindsay v. Public Serv. Co*., 725 F. Supp. 278 (W.D.N.C. 1989).

Colorado statutes protect architects, contractors, builders or builder vendors, engineers, inspectors, manufacturers or sellers of products, and also manufacturers, sellers, or lessors of new manufacturing equipment. Colo. Rev. Stat. 13-80-104, 13-80-106, 13-80-107 (1995).

Virginia specifically *denies* protection to material providers as seen in Va. Code Ann. @ 8.01-250 (1995): "The limitation prescribed in this section shall not apply to the manufacturer or supplier of any equipment or machinery or other articles installed in a structure upon real property..."

Most states however are not as clear in stating who is protected and who is not. The statutes of repose merely say entities that construct improvements to real property are protected. However, the legislatures have not told the courts what an "improvement" is or what a "constructor of an improvement" is. It has been left to the courts to determine the extent of the protection.

For example California's Code of Civil Procedure @ 337.15 (1995) states:

> “(a) No action may be brought to recover damages from any person, or the surety of a person, who develops real property or performs or furnishes the design, specifications, surveying, planning, supervision, testing, or observation of construction or construction of an improvement to real property more than 10 years after the substantial completion of the development or improvement...”

Little, if any doubt existed in early litigation relating to statutes of repose, that engineers, and contractors are clearly protected by the statutes. However, it was not clear if material providers, suppliers, and manufacturers to the construction industry were protected. *Lamb v. Wedgewood S. Corp.*, 308 N.C. 419, 302 S.E.2d 868 (1983) and *Turner Constr. Co. v. Scales*, 752 P.2d 467 (Alaska 1988) (decided prior to the 1994 amendment). Because of the potential protection a statute of repose offers, manufacturers and material suppliers have aggressively sought protection through the courts when a statute, such as California's, is not clear. The extent to which manufacturers and material providers have been successful in convincing judges that the statutes apply to them varies.

Several states have developed case law holding that the statutes of repose do not apply to a manufacturer of building materials used in an improvement to real property. Designers, manufacturers and installers of asbestos-containing materials have been major litigators in the battle to extend protection of a statute of repose to material suppliers in general, and themselves in particular. They have not been successful in doing so. See *Hebron Pub. Sch. Dist. No. 13 v. United States Gypsum Co.*, 475 N.W.2d 120 (N.D. 1991) and *Corbally v. W.R. Grace & Co.*, 993 F.2d 492 (5th Cir.) (This author has not reviewed every case involving asbestos related material - some litigation might have been successful).

The Illinois statute of repose protects professionals who design, plan, supervise, observe or manage the construction of a building, or actually construct an improvement to real property. The defendant's role in manufacturing and supplying fireproofing material did not fall within any of the activities specifically enumerated in the statute, and therefore, the Defendant was not afforded the protection of the statute of repose. *Landry v. Keene Corp.*, 811 F. Supp. 367 (N.D. Ill. 1993).

In the event a contractor or specialty subcontractor is involved in an injury lawsuit, these parties should understand the extent of the protection provided them by their jurisdiction’s statute of repose. A contractor has little, if any, liability for injuries relating to construction project once the statute of repose has run. Specialty subcontractors, manufacturers and material providers however may continue to be liable.

Improvement Analysis

Many states have developed an "improvement analysis" approach to determine whether or not the statute of repose protects a defendant. This requires the courts to develop different categories into which products and materials can be placed. Products placed in the "improvement" category are protected, products in other categories are not.

The definition of improvement vs. fixture; trade fixture; component part; and/or material, has historically given courts trouble and produced inconsistent results. It continues to do so.

If the defendant can convince the court its product is an "improvement" to real property, the defendant can be protected. The definition of improvement has become very broad in recent years due to statute of repose litigation. A Texas court stated that the term "improvement" includes fixtures, "all betterments to the freehold", and "everything that permanently enhances the value of the premises", but does not include material or component parts. *See Dubin v. Carrier Corp.*, 731 S.W.2d 651 (Tex.App.-Houston 1987 no writ) and *Rodarte v. Carrier Corp.,* 786 S.W.2d 94 (Tex.App.-El Paso 1990).

In Michigan, a "stack calendar" and a two-story, block-long papermaking machine (of which the stack calendar was an essential component) were determined to be improvements to real property, and therefor subject to the protection of the statute of repose. The court held the statute of repose prevented the plaintiff from seeking monetary relief for injuries from the manufacturer of the stack calendar.

The court looked at several factors to determine that the stack calendar and the papermaking machine were improvements to real property. These factors included: the value added to the property; the integral nature of the component and the machine; the permanency of placement of the stack calendar and paper-making machine; and their relationship to business occupants and the land. These factors meant that the stack calendar and the papermaking machine were an "improvement to real property" entitling the maker of the stack to protection of the statutes of repose. Plaintiff's claims for injury arising after the running of the statute (six years in this case) were dismissed. *Matthews v Beloit Corp.*, 807 F. Supp 1289 (1993) (in reference to MSA @ 27A.5805).

In Washington the court stated that the construction and installation of an escalator constituted an improvement upon real property. The six-year statute of repose barred a product liability claim arising more than six years after installation of the escalator. *Highsmith v. J.C. Penny & Co.*, 39 Wash. App. 57, 691 P.2d 976 (1984)(Statute of Repose referred to as a statute of limitation in that state). Underground power lines are improvements to real property within the meaning of this section. *Washington Natural Gas Co. v. Tyee Constr. Co.,* 26 Wash. App. 235, 611 P.2d 1378, review denied, 94 Wash. 2d 1011 (1980). A court in Washington stated that the term "improvement on real property" as used in many Statutes of Repose is frequently broader than the term "fixture." *Pinneo v. Stevens Pass, Inc.*, 14 Wash. App. 848, 545 P.2d 1207, review denied, 87 Wash. 2d 1006 (1976).

Therefore, under an "improvement analysis" a manufacturer may or may not be protected, depending on its ability to characterize its product as an improvement. This test has been difficult to apply in the area of real estate law, and continues to be difficult to apply in the area of statute of repose litigation. This test produces inconsistent results. It also is difficult to predict how a court will rule, unless you apply the "follow the money" test. The court is likely to rule in favor of the side with the most money. This is not because of fraud or graft, but because of ability to hire convincing attorneys. The cost of litigation in jurisdictions using this test can be expected to be higher and also more time-consuming.

Activity/Annexation Analysis

Rather than adopt the difficult-to-apply improvement analysis, many states have adopted an "activity analysis" or "annexation analysis". This type of analysis differs in its fundamental focus from an improvement analysis. The improvement analysis focus on a *description of the product* as an improvement, component part, material or whatever other categories have been recognized by the particular court. On the other hand, an activity analysis focuses on the *work done by the entity* seeking protection of the statute. Entities, which engage in substantial and/or significant activities in installing or incorporating their product into/onto the real property, are protected. *Sonnier v. Chisholm-Ryder Co.,Inc.,* 909 S.W.2d 475 (Tex. 1995)(denying protection to a manufacturer of a commercial tomato chopper because it did not annex the product to the realty, even though the product was an improvement). Entities that provide standard products, generally available to the public are not protected. *People v. Asbestospray Corp.,* 247 Ill. App. 3d 258, 186 Ill. Dec. 462, 616 N.E.2d 652 (4 Dist.), appeal denied, 152 Ill. 2d 564, 190 Ill. Dec. 895, 622 N.E.2d 1212 (1993).

In addition to being in conformity with the purpose of the statute of repose, an activity analysis is easier to apply, offers more consistent results, and offers greater predictability in the law. The activity analysis provides protection to fewer entities than the improvement analysis. The entities not protected by the activity analysis, but who may be under the improvement analysis are wealthy manufacturers of standard products and/or equipment.

Some courts have gone a step further and extended protection of the statute of repose to manufacturers who custom-make products away from the construction site. These products must be specifically manufactured for a particular project and then installed by the manufacturer to receive protection. *Herriott v. Allied-Signal, Inc.,* 801 F. Supp. 52 (N.D. Ill. 1992), aff'd, 998 F.2d 487 (7th Cir. 1993).

Missouri has gone a step further and extended protection of its statute to a manufacturer of custom-made products for a particular construction job, even if it does not itself incorporate the product into the realty. Planning and designing a custom-made product intended to meet the special needs of a particular construction project falls within the protection of the statute. *Blaske v. Smith & Entzeroth, Inc.,* 821 S.W.2d 822 (Mo. 1991).

The test outlined by the court in the Blaske case offers the broadest protection to manufacturers, and still is in conformity with the purpose of a statute of repose. This test should be adopted by every state. The purpose of the statutes of repose is to protect designers and builders of improvements to real property, because each construction project is unique. "No two pieces of real estate are identical, and each presents its own unique problems and solutions. There is no such thing as a mass-produced improvement to real property." *Freezer Storage, Inc. v. Armstrong Cork Co.,* 476 Pa. 270, 382 A.2d 715, 719, (Pa. 1978).

In summary, given the present state of the law in many jurisdictions, a manufacturer of standard products, such as air conditioners, will not be protected by the statute of repose, unless it actually installs the product into the construction. A manufacturer of specialty or custom-made components incorporated into a construction project will not be protected unless it installs the component, or performs some role related to the actual construction site. The better rule would be the Blaske rule, which gives protection of the statute of repose to manufacturers of specialty or custom-made components incorporated into a construction project, whether or not the manufacturer installed the component.

Conclusion

Statutes of limitation prevent lawsuit from being filed sometime after a claim arises. Statutes of Repose prevent lawsuits from being filed sometime after the completion date of a construction project. Statutes of Repose traditionally protect contractors, architects and engineers. The extent to which they protect manufacturers and material suppliers to the construction industry varies with the jurisdiction.

The purpose of a statute of repose is to protect designers and builders of improvements to real property from claims because of the unique problems associated with construction. Designers and builders of real property improvements are unable to mass-produce their products or to pre-test them. In addition, each real property improvement is unique, and not subject to standardization and testing that can eliminate injuries.

Two differing theories have developed in the case law to determine whether or not a manufacturer or material supplier is protected by a statute of repose: the improvement analysis and the activity analysis.

The improvement analysis focuses on the product, or item installed on the property. If the product is determined to be an improvement, the manufacturer or material provider is protected. The definition of “improvement” has proved to be a difficult one for the courts, and consistency and predictability are missing from the law. The results of the lawsuits applying the improvement analysis are not always in conformity with the purpose of the statute of repose.

In contrast to the improvement analysis, several courts have developed the activity analysis. Courts adopting this theory extend protection of the statute of repose to those manufacturers and material providers who engage in substantial on-site construction related activity.

An activity analysis may protect a fewer numbers of entities than the improvement analysis. However, the activity analysis is more consistent with the purpose of a statute of repose – to protect persons actually involved in the construction activity. The statutes of repose are designed to protect the construction industry, not the manufacturing industry. If state legislatures wish to protect equipment manufacturers they can, and many have. Courts should not extend protection to these entities merely because their products may be labeled "improvements".

One state, Missouri, has extended protection of its statute of repose to the fullest extent, while still being in conformity with the purpose of the statute. Manufacturers who install products into/onto realty are protected; in addition manufacturers who custom-make products incorporated into real property are also protected. All states which have a statute of repose should employ the activity analysis as adopted by Missouri.

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CASES

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Md. Cts. & Jud. Proc. Code @ 5-108 (Supp. 1991)

Tex. Civ. Prac. & Rem. Code § 16.009

Va. Code @ 8.01-250 (1984)

Va. Code Ann. @ 8.01-250 (1995)

Appendix A

Statutes and Constitutionality Status of State Statutes of Repose
(For reference only. Be sure to check your particular state for latest law.)

Alabama: Statute declared unconstitutional in: *Jackson v. Mannesmann Demag Corp*., 435 So. 2d 725 (Ala. 1983) (holding that the statute of repose violates open courts provision).

Alaska: Statute declared unconstitutional in: *Turner Construction Company, Inc. v. Scales*, 752 P.2d 467 (Alaska 1988) (finding statute violates equal protection because it classifies design professionals). See new statute not yet attacked: Alaska Code 09.10.140 (1995).

Arizona: Ariz. Rev. Stat. @ 12-552 (Supp. 1991) (eight years); NO CONSTITUTIONAL ATTACK YET.

Arkansas: Ark. Stat. @ 16-56-112 (1987) (five years), constitutionality of predecessor, Ark. Stat. @ 37-238, upheld in *Carter v. Hartenstein*, 248 Ark. 1172, 455 S.W.2d 918 (Ark. 1970).

California: Cal. Civ. Proc. Code @ 337.15 (1982) (ten years), constitutionality upheld in *Barnhouse v. City of Pin*ole, 133 Cal. App. 3d 171, 183 Cal. Rptr. 881 (1982).

Colorado: Colo. Rev. Stat. @ 13-80-127 (1987) (six years), constitutionality upheld in <=5> *Yarbro v. Hilton Hotels Corporation*, 655 P.2d. 822 (Colo. 1982); Statute of Repose now found in Rev. Stat. @ 13-80-104 (1995).

Connecticut: Conn. Gen. Stat. Rev. @ 52-584a (1991) (seven years), constitutionality upheld in *Zapata v. Burns*, 207 Conn. 496, 542 A.2d 700 (1988).

Delaware: Del. Code tit. 10, @ 8127 (1974) (six years), constitutionality upheld *in Cheswold Volunteer Fire Company v. Lambertson Construction Comp*any, 489 A.2d 413 (Del. 1984).

District of Columbia: D.C. Code @ 12-310 (1989) (ten years), constitutionality upheld *in Britt v. Schindler Elevator Corporation*, 637 F.Supp 734 (D.D.C. 1986).

Florida: Statute declared unconstitutional. *Overland Construction Company, Inc. v. Sirmons*, 369 So. 2d 572 (Fla. 1979) (stating that the statute violates access to the courts).

Georgia: Ga. Code @ 9-3-51 (1982) (eight years), constitutionality upheld in Mullis v. Southern Company Services, Inc., 250 Ga. 90, 296 S.E.2d 579 (1982).

Hawaii: Statute declared unconstitutional in: *Fujioka v. Kam*, 55 Hawaii 7, 514 P.2d 568 (1973) (finding a violation of equal protection).

Idaho: Idaho Code @ 5-241 (1990) (six years), constitutionality upheld *in Twin Falls Clinic & Hospital Building Corporation v. Hamill*, 103 Idaho 19, 644 P.2d 341 (1982).

Illinois: Ill. Rev. Stat. ch. 110, para. 13-214(b) (Supp. 1991) (ten years), constitutionality upheld in *Cross v. Ainsworth Seed Co.*, 199 Ill. App. 3d 910, 145 Ill. Dec. 927, 557 N.E.2d 906 (1990), but see *Skinner v. Anderson*, 38 Ill. 2d 455, 231 N.E.2d 588 (1967), which held a predecessor statute unconstitutional on special legislation grounds.

Indiana: Ind. Code @ 34-4-20-2 (1968) (twelve years), constitutionality upheld *in Beecher v. White*, 447 N.E.2d 622 (Ind. 1983).

Iowa: Iowa does not appear to have statutes of repose.

Kansas: Kansas has statutes of repose, but they are not specifically for architects and builders for improvements to real property.

Kentucky: Statute declared unconstitutional in: *Tabler v. Wallace*, 704 S.W.2d 179 (Ky. 1985), cert.denied, 479 U.S. 822, 107 S. Ct. 89, 93 L.Ed. 2d 41 (1986) (holding that the five year statute of repose violated special legislation clause).

Louisiana: La. Rev. Stat. @ 9:2772 (1991) constitutionality upheld *in Burmaster v. Gravity Drainage District No. 2*, 366 So. 2d 1381 (La. 1978). (10 year statute).

Maine: Maine Rev. Stat. @ 14-752-A (1980) (actions must be brought against design professionals four years after malpractice or negligence occurs but not more than ten years after substantial completion of services provided); NO CONSTITUTIONAL ATTACK YET

Maryland: Md. Cts. & Jud. Proc. Code @ 5-108 (Supp. 1991) (twenty years after the date the entire improvement first becomes available for its intended use, or ten years in an action against architects, professional engineers, or contractors), constitutionality upheld *in Whiting-Turner Contracting Company v. Coupard*, 499 A.2d 178 (Md. 1985).

Massachusetts: Mass. Gen. L. ch. 260, @ 2B (Supp. 1991) (six years after the earlier of the opening of the improvement to use or substantial completion of the improvement & taking of possession for occupancy by the owner), constitutionality upheld in *Klein v. Catalano*, 386 Mass. 701, 437 N.E.2d 514 (1982).

Michigan: Mich. Comp. Laws @ 600.5839(1) (1987) (six years after time of occupancy of completed improvement, use, or acceptance of the improvement, or one year after defect is discovered or should have been discovered; however, no action can be maintained ten years after the time of occupancy of the completed improvement, use, or acceptance of the improvement), constitutionality upheld in *O'Brien v. Hazelet & Erda*l, 410 Mich. 1, 299 N.W.2d 336 (1980).

Minnesota: Minn. Stat. @ 541.051 (Supp. 1991) (ten years), constitutionality upheld in *Calder v. City of Crystal*, 318 N.W.2d 838 (Minn. 1982).

Mississippi: Miss. Code @ 15-1-41 (Supp. 1991) (six years), constitutionality upheld *in Reich v. Jesco, Inc.*, 526 So.2d 550 (Miss. 1988).

Montana: Mont. Rev. Code @ 27-2-208 (1991) (ten years), constitutionality of predecessor, Mont. Rev. Code @ 93-2619, upheld in *Reeves v. Ille Electric Company*, 551 P.2d 647 (Mont. 1976).

Nebraska: Neb. Rev. Stat. @ 25-223 (1989) (ten years beyond time of act giving rise to the cause of action), constitutionality upheld in *Williams v. Kingery Construction Company*, 225 Neb. 235, 404 N.W.2d 32 (1987); Nev. Rev. Stat. @ 11.204 (1991) (eight years), constitutionality upheld in *Wise v. Bechtel Corporation*, 104 Nev. 750, 766 P.2d 1317 (Nev. 1988).

New Hampshire: Statute declared unconstitutional in*: Henderson Clay Products, Inc. v. Edgar Wood & Associates, Inc*., 122 N.H. 800, 451 A.2d 174 (1982) (holding the statute of repose unconstitutionally discriminatory).

New Jersey: N.J. Rev. Stat. @ 2A: 14-1.1 (1987) (ten years), constitutionality upheld in *Rosenberg v. Town of North Bergen*, 61 N.J. 190, 293 A.2d 662 (1972).

New Mexico: N.M. Stat. @ 37-1-27 (1990) (ten years), constitutionality upheld *in Terry v. New Mexico Hwy. Comm'n*, 98 N.M. 119, 645 P.2d 1375 (1982).

New York: New York has statutes of repose, but they are not specifically for architects and builders for improvements to real property.

North Carolina: N.C. Gen. Stat. @ 1-50(5) (Supp. 1991) (six years), constitutionality upheld in *Lamb v. Wedgewood South Corporation*, 308 N.C. 419, 302 S.E.2d 868 (N.C. 1983).

North Dakota: N.D. Cent. Code @ 28-01-44 (1991) (ten years), constitutionality upheld in *Bellemare v. Gateway Builders, Inc*., 420 N.W.2d 733 (N.D. 1988).

Ohio: Ohio Rev. Code @ 2305.131 (1990) (ten years), constitutionality upheld *in Sedar v. Knowlton Construction Company*, 49 Ohio St. 3d 193, 551 N.E.2d 938 (1990).

Oklahoma: Okla. Stat. tit. 12, @ 109 (1988) (ten years), constitutionality upheld *in St. Paul Fire & Marine Insurance Company v. Getty Oil Company*, 782 P.2d 915 (Okla. 1989).

Oregon: Ore. Rev. Stat. @ 12.115 (1988) ("In no event shall any action for negligent injury to person or property of another be commenced more than ten years from the date of the act or omission complained of."), constitutionality upheld in *Josephs v. Burns*, 260 Ore. 493, 491 P.2d 203 (Ore. 1971).

Pennsylvania: Pa. Stat. tit. 42, @ 5536 (1981) (ten years) constitutionality of predecessor, Pa. Stat. tit. 12, @ 65.1, upheld in *Freezer Storage, Inc. v. Armstrong Cork Company*, 476 Pa. 270, 382 A.2d 715 (Pa. 1978).

Rhode Island: R.I. Gen. Laws @ 9-1-29 (1985) (ten years), constitutionality upheld *in Leeper v. Hillier Group, Architects Planners, P.A.*, 543 A.2d 258 (R.I. 1988).

South Carolina: Statute declared unconstitutional in: *Broome v. Truluck*, 270 S.C. 227, 241 S.E.2d 739 (S.C. 1978) (stating that the statute violates equal protection).

South Dakota: Constitutionality not upheld in*: Daugaard v. Baltic*, 349 N.W.2d 419 (S.D. 1984) (finding the statute to violate open courts provision).

Tennessee: Tenn. Code Ann. @ 28-3-202 (1980) (four years), constitutionality upheld in *Harmon v. Angus R. Jessup Associates, Inc*., 619 S.W.2d 522 (Tenn. 1981).

Texas: Tex. Civ. Prac. and Rem. Code @ 16.008 (1986) (ten years), constitutionality upheld in *Suburban Homes v. Austin-Northwest Development Company*, 734 S.W.2d 89 (Tex.App. 1987).

Utah: Statute declared unconstitutional in: *Horton v. Goldminer's Daughter*, 785 P.2d 1087 (Utah 1989) (holding the statute violates open courts provision).

Virginia: Va. Code @ 8.01-250 (1984) (five years), constitutionality upheld *in Hess v. Snyder Hunt Corporation*, 240 Va. 49, 392 S.E.2d 817 (Va. 1990).

Vermont: Does not appear to have statutes of limitations.

Washington: Wash. Rev. Code @ 4.16.310 (1988) (six years), constitutionality upheld in *Yakima Fruit & Cold Storage Co. v. Central Heating & Plumbing Co*., 81 Wash. 2d 528, 503 P.2d 108 (1972).

West Virginia: W.Va. Code @ 55-2-6a (Supp. 1991) (ten years). NO CONSTITUTIONAL ATTACK YET.

Wisconsin: Statute declared unconstitutional in: *Funk v. Wollin Silo & Equipment, Inc*., 148 Wis.2d 59, 435 N.W.2d 244 (Wis. 1989) (finding that the six year statute of repose violates equal protection).

Wyoming: Statute declared unconstitutional in: *Phillips v. ABC Builders, Inc*., 611 P.2d 821 (Wyo. 1980) (holding that the statute of repose violates open courts, equal protection, and special laws clauses).

Journal of Construction Education
Summer 1997, Vol. 2, No. 2, pp. 133-145

1522-8150/97/$3.00/General Manuscript

A Comparison Between Steel and Wood Residential Framing Systems

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A cost comparison study between wood and steel for residential framing in Florida was performed to show the cost effectiveness of each material. Advantages and disadvantages of steel and wood were reviewed as well as their sustainability from a life-cycle perspective. It was found that at the present time wood and steel walls were approximately similar in cost while the use of steel for roof framing is not cost competitive with conventional wood. Using steel for interior framing and wood for the exterior would be advisable at this time.

Key words: Residential Framing, Cost Comparison, Sustainability, Steel, Wood

Introduction

Wood frame construction has been the unchallenged norm for residential building for a very long time because of its satisfactory performance, availability, and relatively low cost. However, over the past few years, volatile wood prices, declining quality of framing lumber and environmental issues have raised serious concerns regarding the use of wood as a favorable option to residential construction.

The sharp fluctuations in the lumber prices is evident from the fact that the framing lumber composite price between October 1992 and February 1993 increased by nearly 100 percent, while the average weekly change in the framing lumber composite price varied in the year 1993, between $10 and $15 per 1,000 board feet, or about three times the rate of change experienced throughout the 1980s. The direct effect of the erratic cost of wood on the cost of a house is seen in Table 1. It shows how the framing lumber and structural panel costs increase with the lumber composite price. Due to such fluctuations in lumber costs, the need for assessing the alternatives to wood-frame construction becomes essential.

The need for alternative materials and methods for residential construction is intensely felt in Florida, particularly since concerns over termite and decay problems and high-speed winds discourage interests in wood framing. Recently, steel has emerged as a viable alternative to wood as it offers durable and hurricane resistant construction. With the various alternative systems available, steel framing has gained prominence primarily because it offers price stability and a simple piece-by-piece substitution for wood. This has enabled the builders to adjust to the new material without worrying about learning a whole different approach to framing. The hurricane resistant quality of a steel house has increased interest in steel amongst Floridians. However, it is not clear how the application of such alternative material compares with wood.

Table 1

Cost of Lumber in 2,000 Square Foot Home

Cost Per 1,000 Board Feet	Framing Lumber	Structural Panel	Lumber Costs Per House
$200	$3,488	$1,394	$4,882
300	5,232	2,091	7,323
400	6,976	2,788	9,764
500	8,720	3,486	12,206
600	10,464	4,183	14,647
700	12,208	4,880	17,088

Source: Nation's Building News, February 14, 1994.

This paper reports to result of a comparison study between wood and steel for residential framing. It includes a comparison of practical feasibility and in-place labor and material requirements of wood and steel framing for residential construction. By evaluating the two materials in terms of feasibility, quality and costs, the objective is to stimulate homeowners to investigate the material option more thoroughly.

Literature Review

A comparative study of in-place costs of wood and steel framing was performed by the Forest Products Laboratory for the U.S. Department of Agriculture in 1979. Primarily, the study investigated the residential market shares of wood and steel framing and then compared the in-placed costs of the two framing systems by dividing it into three major categories – flooring systems, load-bearing wall systems, and non-load-bearing partitions. These systems were analyzed in terms of material requirement, material costs, labor requirement and labor costs to calculate the total in-place costs for the two framing systems. The study concluded that both wood and steel flooring and load-bearing walls were approximately similar in cost while steel non-load-bearing partitions continued to enjoy a large price advantage.

An analysis of the sustainability of steel versus wood from a life-cycle perspective was conducted by Scientific Certification Systems, they evaluated the environmental burdens of the two systems. These burdens include the use of resources, energy consumed and pollution generated over each stage of a material's life cycle. By assessing the comparative severity of these environmental burdens, the relative degree of sustainability of the two materials to perform the same function is assessed. The study concludes that in the use of steel versus wood framing in residential construction in the U.S., steel appears to have clear advantages in the resource depletion and ecosystem depletion areas, while differences in energy use between wood and steel are insignificant.

Another study conducted by the Environmental Building News in 1994, again investigates steel and wood framing systems from a sustainability point of view. The study evaluates the two systems in terms of thermal performance, resource extraction and manufacturing process, and the advantages and disadvantages the two systems offer. The study concludes that the thermal performance of steel still remains to be resolved in a more environmentally favorable way. Also, substituting steel in conventional wood framing pattern is under-utilization of steel strength. On the other hand, the main area of concern for wood remains to be ecosystem depletion.

A study conducted by National Association of Home Builders (NAHB) in 1994, focuses in finding alternatives framing materials to wood framing system due to high fluctuations in lumber prices. It includes an evaluation of the alternatives' practical feasibility and in-place labor and material requirements as compared to wood framing in comparable homes. In-place costs of the three alternative framing materials – foam-corestructural sandwich panels, light-gauge steel framing, and welded-wire sandwich panels – were determined and compared with conventional wood framing.

Results indicate that certain aspects of light-gauge steel are within the range that might be expected to be cost-effective with wood. The other alternatives, while offering structural advantages, presently do not appear to be cost competitive with wood.

Methodology

House Selection

A typical residential floor plan that represents the plans currently used in Florida is selected for the house to be used in this study. Two sets of survey data have been used in selection of the construction characteristics of this dwelling unit. They are:

1. The 1987-19993 Residential Data Summary developed by the Shimberg Center for Affordable Housing, and
2. Assessment of Damage to Single-Family Houses Caused by Hurricane Andrew developed by NAHB Research Center.

Table 2 and 3 show the summary characteristics of the houses in Florida according to aforementioned surveys. From Table 2, it is evident that, the average size of a house in Florida, ranges between 1400 SF to 1700 SF (24.1%), and incorporates 3-bedroom (60.4%). It is gathered from Table 3., that the other prominent characteristics include construction typically involving a single story structure (80%), and preferably with a gable roof (81%). Therefore, a feasible selection of a 1500 square foot, 3-bedroom, one-story gable house with slab-on-grade foundation is made.

Figure 1 shows the typical ground floor plan of the house chosen for the study. The study home measures 1470 square feet. All framing elements of the wood-framing house are designed to be fabricated in Southern Pine, Grade 2 lumber. While, all framing elements in steel house are designed to be fabricated in light-gauge steel. Wall studs in each case are spaced at 24 inches on center with load-bearing studs located directly in-line with pre-engineered roof trusses.

Table 2

Percent Application Preference for Intent Test

Interval Number	Time Interval	Case Count For Interval	Test Applied	% Test Applied	Test Not Applied	% Test Not Applied
1	1858-1867	1	0	0	1	100.0
2	1868-1877	1	0	0	1	100.0
3	1878-1887	3	2	67.0	1	33.0
4	1888-1897	11	9	81.0	2	18.0
5	1898-1907	22	10	45.0	12	48.0
6	1908-1917	25	13	52.0	12	48.0
7	1918-1927	7	3	43.0	4	57.0
8	1928-1937	4	3	75.0	1	25.0
9	1938-1947	8	3	38.0	5	62.0
10	1948-1957	10	7	70.0	3	30.0
11	1958-1967	12	4	33.0	8	67.0
12	1968-1977	20	4	20.0	16	80.0
13	1978-1987	33	9	27.0	24	73.0
14	1988-1991	18	3	17.0	15	83.0
	TOTALS	175	70	40.0	105	60.0

Table 3

Summary Description of Houses Surveyed in Florida

Home Characteristics	Area in SF	Percentages
Number of Stories	1	80
	1-1/2	2
	2	18
Roof Type	Gable	81
	Hip	13
Roofing Materials	Comp. Shingle	40
	Built-Up	8
	Flat Tile	15
	Clay Tile	3
Roof Sheathing Mat.	Plywood	89
	OSD	6
Wall Type	Block	96
	Wood	4
Foundation Type	Slab	100

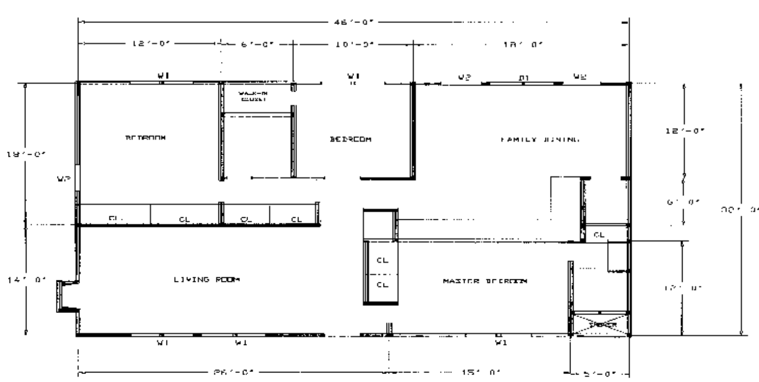

Figure 1. Typical House Plan for Study

The steel and the wood houses are generated using the typical study plan. The steel house is designed as the traditional stick construction, similar to the wooden counterpart, whereby there is one-for-one substitution of steel for wood. Both the houses are designed to withstand high velocity winds (110 mph), addressing the factor of destruction caused by the hurricane in the region of Florida.

The steel framing is designed in accordance with the "Minimum Design Load for Building and other Structure" provided by the American Society of Civil Engineers in ANSI/ASCE 7-93. Figure 2 shows the typical section through the steel-framed house. There is a roof overhang of 2-feet, with the slope of roof being 5 in 12. The shear walls represent the two adjacent exterior and interior plywood sheathing.

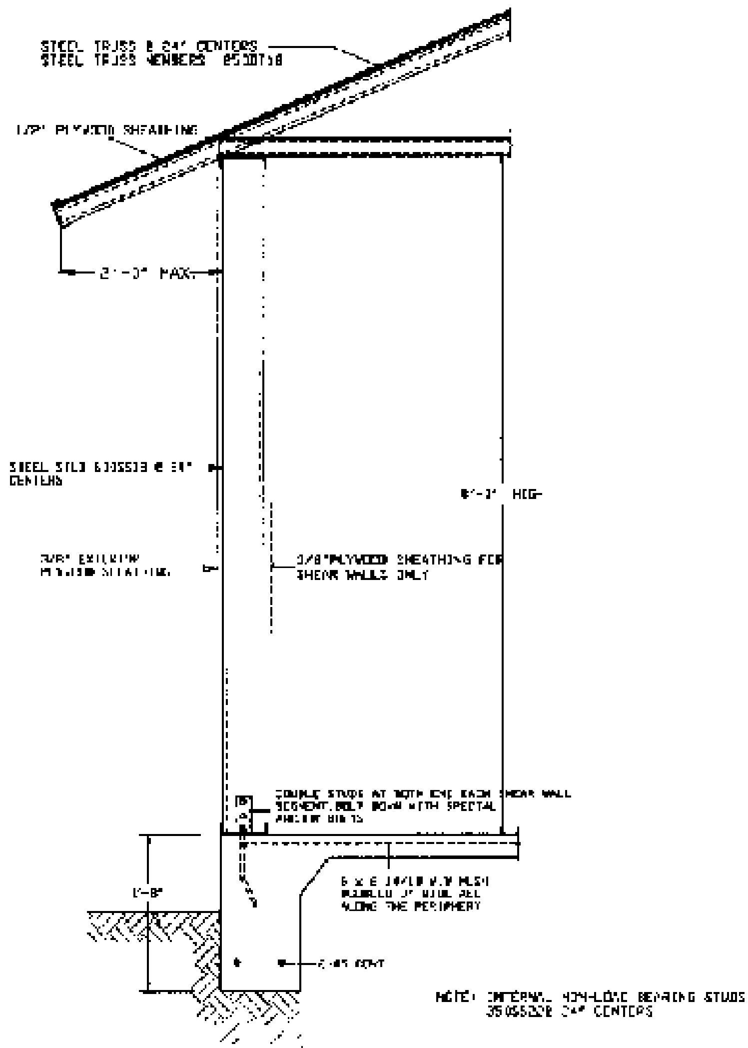

Figure 2. Typical Section through Steel Frame House

The design of a hurricane-resistant wood house is adopted from the details provided by John E. Meeks, P.A. Consulting Engineer through the Shimberg Center for Affordable Housing.

However, the appropriateness of the sections utilized for the wood stud walls and pre-engineered trusses to withstand winds with 110 mph velocity were checked. Figure 3. Shows the typical section of the wood-framed house.

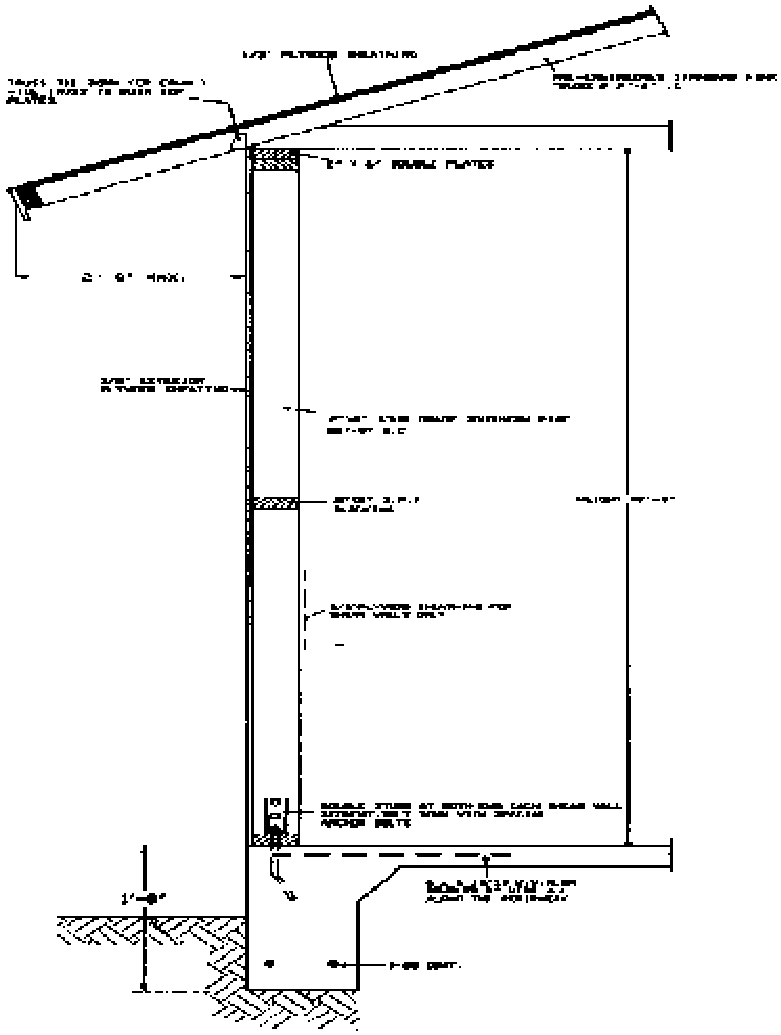

Figure 3. Typical Section through Wood Frame House

Common framing elements for steel and wood framed house involve:

1. Two adjacent external walls representing shear walls, incorporating 3/8" plywood sheathing on the interior face,
2. External wall sheathing consisting of 3/8" thick plywood,
3. Roof sheathing consisting of ½" thick plywood.

The finishes for the two houses are not considered in the study primarily because it will not affect the cost if they are similar. Moreover, only elements that affect the cost are considered.

Steel vs. Wood Cost Comparison

The cost of construction is calculated for both wood and steel framing systems. The cost includes, both, the cost of materials and the cost of labor. The cost of material is determined directly from the local lumber suppliers and steel manufacturers, while the cost of labor is calculated using 1995 Means Cost Data for Residential Construction. The material cost of the wood frame house is summarized in Table 4, and that of steel in Table 5.

Table 4

Wood Framing – Material Cost

Classification	Quantity	Unit	Cost/Unit $	Total Cost $	Comments
2x6 Section #2 Pine, 8 ft.	196	EA	3.79	743	Load bearing walls
2x4 Section #2 Pine, 8 ft.	216	EA	2.19	473	Non-load bearing walls
2x12 Section #2 Pine, 12 ft.	12	EA	17.79	213	Headers
32 ft Span fink truss	24	EA	55.00	1320	Prefabricated truss
2x4 Roof blocking, 2’ long	29	EA	0.55	16	
3/8" CDX plywood	68	Sheet	12.39	843	Wall sheathing
½" CDX plywood	58	Sheet	14.09	817	Roof sheathing
Nails				200	
Misc. Hardware				250	
Subtotal				4875	
Sales Tax @ 6%				293	
Total Material Cost				5168	

Table 5

Steel Framing – Material Cost

Classification	Quantity	Unit	Cost/Unit $	Total Cost $	Comments
600SS18 Stud (Exterior)	936	LF	0.673	630	Load bearing walls
600SS18 Exterior Track	345	LF	0.673	232	
600SS18 Headers	90	LF	0.673	61	
350SS22 (Interior)	875	LF	0.326	285	Non-load bearing walls
350SS22 Interior Track	385	LF	0.326	126	
250DT18 for Trusses	24	EA	80.00	1920	On-site fabricated truss
3/8" CDX Plywood	68	Sheet	12.39	843	Wall Sheathing
½’ CDX Plywood	58	Sheet	14.09	817	Rood Sheathing
Screws and hardware				600	
Subtotal				5514	
Sales Tax @ 6%				331	
Total Material Cost				5845	

The two houses are compared in terms of wall and roof framing including:

1. Wall Framing (External and Internal): Bottom plate, studs, top plate, header, internal shear-wall sheathing, external sheathing, and blocking.
2. Roof Framing: Pre-engineered wood trusses, on-site fabricated steel trusses, blocking between trusses, and roof sheathing.

As seen from Table 4 and 5, material cost for the steel house is about 12% higher than the lumber houses. However, as compared to the relatively stable price of steel, the constant fluctuations in lumbar prices may leave only a little edge for wood to be more cost effective in term of material cost.

Table 6 compares light gauge steel walls to conventional wood-framed walls and summarizes the unit costs for materials, labor, and equipment. Values are expressed in dollars per linear foot of an 8-foot high wall. The material costs for light-gauge steel walls are 3.5% less than for wood walls. This table reflects the price of lumber during May 1995. When comparing unit costs for new construction, an estimate reflecting the current costs will have to be made.

Table 6

Wall Framing Unit Costs

Wall Framing Unit Costs
Light Gauge Steel vs. Conventional Wood

	Material Costs $/LF*	Labor Costs $/LF	Equip. Costs $/LF	Total Costs $/LF
Light Gauge Steel Framing	7.93	4.66	0.29	12.88
Wood Framing	7.99	4.15	0.26	12.40

*External and internal walls plus external sheathing and internal sheathing at shear walls only.

Table 7 compares roof framing unit costs for the light-gauge steel and wood-framed houses. Values are expressed in dollars per square foot of the roof area. In the roof analysis, sheathing was included with the trusses.

Table 7

Roof Framing Unit Costs

Roof-Framing Unit Costs
Light Gauge Steel vs. Conventional Wood

	Material Costs $/SF of Roof	Labor Costs $/SF of Roof	Equip. Costs $/SF of Roof	Total Costs $/SF of Roof
Light Gauge Steel Roofing	1.79	0.86	0.15	2.80
Wood Roofing	1.43	0.67	0.18	2.28

Factors that contribute to a higher unit rate for light-gauge steel typically include more time spent on fastening together of the pieces. This is because screws simply take more time to install than nails. However, the new pneumatic fasteners and other products being developed will help bring the labor costs down.

Advantages and Disadvantages

The comparison between steel and wood is incomplete without understanding the inherent advantages and disadvantages offered by the two systems, since it immensely influences the choice between the two materials. The concerns of both, the homeowner and the builder, with respect to the two materials are addressed and appraised here.

A finished steel house does not look any different than a finished wood house. With this in mind, an impartial evaluation is made. Table 8, provides a comparison at a glance, between steel and wood, investigating matters of paramount importance to an owner. Amongst these, the consideration for insect resistance, hurricane and earthquake performance, and fire performance directly affect the homeowner's insurance rates. Factors like initial construction cost of the house, as well as the future maintenance cost, influence the choice of material. Understanding the pros and cons of the material will assist in making a wise investment, based on a correct judgment.

Table 8

Comparison Between Steel and Wood at a Glance

Issue of Concern	Steel	Wood
Dimensional Property and stability	Consistent quality, exact dimensions. Steel does not rot, shrink or warp	Inconsistent quality. Wood shrinks, warps which causes movement
Price	Volatile wood prices make steel more predictable. Steel is competitively priced and prices are stable.	Erratic price and quality. Low material costs (at times).
Indoor air quality	Steel is inert, wood releases terpene and treated wood contains toxins.	Untreated wood causes no problem to people.
Thermal efficiency	Steel's thermal performance is poor, but can be resolved by adding exterior insulation or other modification.	Wood is naturally low in conductivity. It insulates well.
Insect resistance	Steel is not attractive to insects.	Wood attracts termites. Preservative-treated wood is safe and effective.
Recycling or Disposal	Steel is recyclable. Magnetically separated easily.	Treated wood is not biodegradable. Non-treated wood is biodegradable. Wood may be salvaged and reused.
Hurricane and Earthquake Performance	Steel can be engineered to sustain high speed wind and seismic loads. Lighter weight of structure reduces damage.	Wood can also be designed to take greater loads, but it makes the structure very heavy.
Fire Performance	Steel does not burn. However, steel losses its strength at high temperatures.	Wood is easily combustible.
Building Codes	Steel framing codes are not standardized.	Wood codes are well established.
Construction Waste	Members are available in a variety of pre-cut, custom and standard shapes and sizes, minimizing construction waste.	The wastage of wood ranges from about 10-20% as compared to steel which is about 1-3%, which can be sold as scrap and recycled.

Environmental Impact and Sustainability Issues

Every form of development has an environmental impact. All basic materials have finite reserves and their extraction result in the release of pollutants into air and water. Energy is also needed to process the materials into useful products. However, by assessing the comparative severity of these environmental burdens, it is possible to obtain important insights into the relative degree of sustainability of various material options used to perform the same function.

Wood is renewable, but that does not mean it is automatically more sustainable than steel. While it is possible to replant trees after cutting, there is no guarantee that replanted trees will grow to the same size or the same quality, or that trees can be continuously re-grown on the same land base. Thus, while it is a fact that trees can be renewed to some degree after a given harvest, such processes would have to be repeatable indefinitely to claim full sustainability.

On the other hand, all steel products can be recycled without degradation or loss of properties. The steel industry has invested a lot of money in environmental and efficiency improvements in the last decade. Energy use and pollution are now way down. However, in spite of improvements, environmental impacts are still significant.

To assess the sustainability as well as the environmental impacts caused by these two materials, it is essential to evaluate these two materials against several environmentally sensitive issues.

From a life-cycle perspective, the measurable factors that characterize the sustainability of a resource include:

- the rate of *resource depletion*
- *extended material use* or recycling
- the direct *energy* required in manufacturing
- *Resource Depletion: Wood vs. Steel*

Wood

It has been estimated that each year, more than 40 million acres of forestlands are lost forever worldwide. Drought and forest fires have totally destroyed several million acres of forest in the U.S. alone resulting in no wood resources and no ecosystems left at all.

Aside from these natural events, the U.S. government has negotiated by mandating that 12 million acres be to be locked up as critical habitat for the spotted owl. Even more discouraging for the wood industry is that fact that, 88% of all national forests in the U.S. not set aside by law are tied up in federal court by environmentalists who wish to make these areas unavailable for timber extraction.

All combined, these factors have substantially reduced the total reserve base of the entire western region of the U.S. resulting in a drop of 29% of the production of lumber. Western softwood lumber production has fallen from nearly 24 billion board feet in the later 1980's to the current production level of 17 billion board feet, and is expected to fall even further in the future.

Currently, the wood that is being extracted is from smaller diameter trees, about 7-inch diameter logs as compared to the 40-inch diameter trees that were harvested 50 years ago. The small diameter trees contain a significant percentage of sapwood requiring more kiln drying, and which yields a greater percentage of low grades of lumber, as compared to the greater diameter lumber which was dry, structurally sound, without knots, and with exceedingly good yields. Also, log-diameter affects the rate of utilization because for a given quantity of lumber, more smaller diameter trees will be required as compared to a fewer bigger diameter trees. Thus, more trees will have to be harvested in case of smaller diameter trees removing a higher proportion of forest cover.

Steel

All raw materials used in manufacturing steel are in plentiful supply. Iron is one of the most abundant minerals on earth. Iron is one of the most abundant minerals on earth. Its reserves are stable and do not face hazards of fire, drought or disease like wood.

Mining practices have improved dramatically, and also, much new steel is recycled from scrap. Furthermore, products made from high-strength steel require significantly less steel per product than regular steel to perform the same function. For example, it takes 380 pounds less steel per car than it did just five years ago.

It is estimated that the amount of steel that would be required to build every new residential house in the U.S. over one year would be around 8 million tons, compared to the total annual output of 88 million tons. Therefore, the need of the residential market can be met without constructing new steel mills or adding capacity to existing mills. However, the raw materials used to make steel include iron ore, limestone, coal and zinc, all of which are non-renewable substances mined from the earth.

Extended Material Use or Recycling

Wood

In the U.S., wood used in residential construction has not found any widespread secondary use. Although, it could be possibly used in engineered wood products, the diminishing grades of wood reduce this extended use critically. This drop in grade is primarily due to the harvesting of much younger trees and the reliance on sapwood rather than dry heartwood. Wood is biodegradable, but most residential wood is treated with toxins and will be required to be handled as hazardous waste.

Steel

Steel has a proven track record of material extension through recycling. In fact, for a given amount of iron ore extracted and used, the steel produced can be continuously reclaimed and recycled without significant losses or degradation. This makes steel much closer to being a sustainable resource than wood. Magnetic separation makes steel the easiest and most economical material to remove from the solid waste stream and contamination is not an issue.

Direct Energy Requirement in Manufacturing

Wood

The manufacture of wood products requires much less process-energy input than steel. Most of the energy in wood is stored solar energy produced by photosynthesis. As the wood grows, it converts carbon dioxide to oxygen, during the process of photosynthesis, storing the carbon even in its manufactured state. The use of wood results in much lower CO_2 emissions than other materials because of the low amount of fossil-fuel energy used in the manufacture of wood materials.

Engineered wood products are provided viable alternatives to solid lumber for some applications. By using fast-growing and underutilized species, they avoid many of the forestry concerns of solid wood products, and they tend to be more stable and uniform in quality then new lumber. However, the manufacturing processes for these products have environmental drawbacks such as increased processing energy and use of fossil-fuel-derived binders. Also, engineered products are still too expensive to replace most lumber in a standard house.

Steel

Steel is one of the most energy intensive industrial materials, generating pollution and waste from all stages of the process, including coking coal, purifying iron, and galvanizing. The process of smelting does galvanization of steel. Wastewaters from zinc smelting facilities can contain a number of heavy metals including cadmium, toxic organic and chlorinated compounds.

The steel industry in the U.S. has made tremendous strides in improving its environmental performance over the past two decades. According to data from Scientific Certification Systems (SCS), since the early 1980s CO_2 emissions have dropped by more than 28%, and SO_2 emissions, responsible for acid rain by 95%.

Conclusions

The rapid escalation of lumber cost over the past few years has increased the cost of wood framing and improved the prospect for steel in the residential market. The results of this study showed that at the present time wood and steel walls are approximately similar in cost while use of steel for roof framing is not cost competitive with conventional wood. A factor that contributes to a higher unit labor cost for steel is the time spent on fastening together of the pieces. This is because screws simply take more time to install than nails.

Steel is over 400 times more conductive of heat than wood, thus wherever steel spans from the inside to the outside of the building envelope, it causes severe thermal bridging. In areas with significant heating or cooling loads, using steel for interior framing and wood for the exterior would be advisable. Steel-framed houses tend to be over designed due to simple wood-to-steel conversions, switching stick-to-stick, rather than truly designed to take advantage of its greater strength and uniformity. Steel should be used in a system that requires for fewer framing members, spaced farther apart.

On the issue of sustainability, steel appears to have clear advantages in the resource depletion, while differences in energy use between wood and steel are insignificant if design modifications due to steel’s high strength are included in life cycle calculations.

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Acknowledgement

The Editor wishes to thank the Department of Industrial Technology and the College of Applied Science and Technology of Illinois State University for their support of the *Journal* creation and operations. Thanks are also due to the Editorial Advisory Board whose names appear on the second page; and to those serving on the Review Board listed above.

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