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## Health and Safety in Tall Building Construction

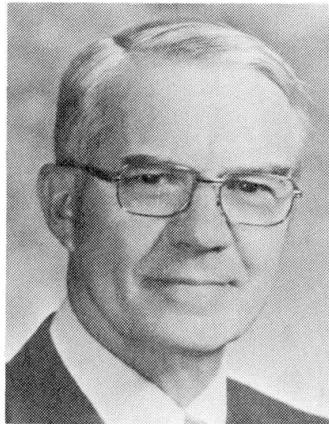
Santé et sécurité dans la construction des maisons hautes

Gesundheit und Sicherheit beim Bau von Hochhäusern

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### SUMMARY

Although definitive statistics are not available, a selective picture has been obtained of tall building construction hazards with respect to health and safety. The most frequent health hazards are fumes, smoke and noise. The most serious accidents are falls through openings, and being struck by falling objects. By far the greatest percentages are due to human error. Suggestions are made to improve safety practice.

### RESUME

Bien que des statistiques précises ne soient pas disponibles, il est possible de décrire la situation des dangers encourus par les ouvriers dans la construction des maisons hautes. Les dangers les plus fréquents pour la santé sont les fumées, les gaz et le bruit. Les dangers d'accident les plus sérieux sont les chutes au travers d'ouvertures et l'atteinte par des objets tombants. Le plus grand pourcentage de ces accidents est dû à l'erreur humaine. Des propositions sont faites pour améliorer la sécurité sur le chantier.

### ZUSAMMENFASSUNG

Obwohl keine genauen Statistiken vorhanden sind, konnte die spezielle Gefahrensituation beim Bau von Hochhäusern in Bezug auf Gesundheit und Sicherheit beschrieben werden. Die häufigsten Gefahren sind für die Gesundheit der Rauch, die Gase und der Lärm. Die häufigsten Unfallgefahren sind der Sturz durch Öffnungen und das Getroffenwerden durch fallende Gegenstände. Der grösste Prozentsatz dieser Unfälle ist auf menschliches Versagen zurückzuführen. Vorschläge zur Verbesserung der Sicherheit auf Baustellen werden unterbreitet.



The total cost for all forms of construction in the USA is about \$250 billion per year. Of this, the cost of accidents exceeds about \$8 billion. This paper explores the nature of this loss of national productivity insofar as tall buildings are concerned, examines trends, and looks to see if improvements can be made. The preparation of this report has been supported in part by the U.S. National Science Foundation.

The tall building is variously reported as "over 6 stories", over 8, over 10, or over 100 ft. depending on the person or jurisdiction queried. In addition to hazards in new construction, health and safety hazards also exist in repair work, rehabilitation, renovation, and demolition. With regard to new construction, the major steps in the process are demolition, excavation, footings, structure, mechanical and finishes.

It was soon determined that of the mass of statistics collected by federal and private agencies, it is not possible at the present time to extract definitive data in the U.S.A. with regard to the high-rise. The tall building would come under the "general building" and "special trade" headings, but it is not possible to separate out how much of it is ordinary building and one-story warehouses or manufacturing facilities, and how much is high-rise.

Therefore, to supplement the available published information on construction safety per se, the following sources were used.

- Personal and telephone interviews
- Lockheed information data base
- New York Times information data base
- Examination of 3 years of the Engineering News Record
- National Safety Council
- Some selected texts
- The Monograph on tall buildings
- Files of the Tall Building Council
- A few personal visits to construction sites

From these sources a selective picture has been obtained of the most frequent hazards; the most serious; some examples; what measures are taken to protect the worker, the public, and property; trends in safety; and some ideas for improving the situation.

With regard to health, the major problems with regard to tall buildings are the following:

- Fumes due to welding (Lead poisoning)
- Toxic dust
- Paint fumes
- Fumes from glues
- Loss of hearing
- Smoke inhalation
- Loss of vision

With regard to tall building accidents, the most requent would appear to be:

- Eye injuries (welding burns, dust, and foreign objects)
- Injury to extremities (thumbs, hands, feet)
- Bodily strains (due to the lifting of loads, for example)
- Fires (space heaters, electrical short-circuit, spark ignited)
- Falls on same level

The most serious accidents are:

- Falls, most particularly down shaft openings for elevators, stairwells, and ducts. Also perimeter falls and falls from topmost skeleton floor.
- Being struck by a falling object
- Caught between two objects

One thinks immediately of the connectors, those structural iron workers who are putting up the building before any safety lines, temporary floors or barriers can be installed. Perhaps because it is so potentially dangerous in tall buildings the record is comparatively good. In an excellent set of data from Ontario, Canada, for the two-year period 1979 and 1980 there were 29,000 injuries, 3,700 of which were falls. Ironworkers were involved in 110 of these. Twelve were connecting at the time of the accident, and only 2 of these involved tall buildings. There were no deaths. So accidents in which tall building connectors are involved appear to be relatively infrequent.

What happens to cause accidents in tall buildings? It's mostly in material handling and falls.

- Barriers are removed (such as covers over shafts) and are not replaced.
- Forms have to be stripped and moved.



- Debris gets underfoot.
- A sudden gust of wind can cause a deep girder to act as a sail.
- Objects can be dropped from above.
- Objects can be knocked or blown over the side.
- A crane can collapse or drop its load.
- A worker can slip.
- Available safety equipment is not utilized.

The list can go on, but the major question is why they happen. With the high-rise, at least, the hazards have always been so great that an abundance of safety procedures have been available for years. There can always be a mechanical failure, and material collapse is a possibility. But over and over again (and frequently "not for publication") the accident is due to human failure. "The body is on the job, but the mind is not". The worker becomes careless. Perhaps he is not fully aware of the danger. He gets in a hurry and "forgets the rules". Or he simply doesn't follow the rules. It is a combination of unsafe acts and unsafe conditions.

Supervision bears a major responsibility here, too. Particularly with regard to foremen educating their work force and checking before and after for potentially unsafe working conditions. And too often the safety officer on a project is not taken seriously or may not be trained for the task at hand.

With regard to costs and numbers, the following is subject to the provisions stated at the beginning about the scarcity of statistics with regard to tall buildings.

- In comparison with death on the highway (52,000 deaths in 1980) the work place is relatively safe.
- For accidents in the work place (1980), construction accounts for more deaths than any other category (2,500). But its rate of 45 per 100,000 workers is exceeded by both mining (50) and agriculture (61).
- If one uses the figure of \$250 billion for the entire construction industry, this means one death per \$100 million and one accident per \$ million.
- Where does the high-rise stand? Most reports suggest a better record, some worse. One report has one death for three tall buildings of about 50 stories in height and a value in excess of \$500 million. One of the three buildings is complete and two are nearing completion. Another report showed two deaths over a ten-year period (75 buildings and \$7 billion). Another reported two deaths (one a spectator) for \$150 million of construction over a year's time. One federal agency reported six deaths on construction projects over the past ten years.

- A scanning of "First Reports of Serious Accidents", a file maintained by OSHA, shows that about one out of 50 of the reports refer to a tall building.

What can be done to prevent accidents? Action in seven areas are required: (1) Safety Regulations, (2) Safety Equipment, (3) Safety Education, (4) Safety Design, (5) Safety Programs, (6) Safety Contracting, (7) Safety Consciousness.

With regard to safety regulations the hazards of high-rise construction have always been so severe that in many cases the federal (OSHA\*) and state regulations have followed after those already established by the major companies. For the smaller, less experienced contractor, OSHA requirements have made them improve, or go out of business.

With regard to safety equipment for the high-rise, as far as wearing apparel is concerned, it is reported that hard hats are the most important, followed by eye goggles and safety belts. The important barriers include perimeter cables, sidewalk sheds, toeboards, and shaft opening covers. There is significant disagreement about use of nets.

With regard to safety education, there is considerable variability. Most high-rise safety education is probably "on the job". On the other hand, there are some cities -- such as Chicago -- where the industry as a whole takes on the responsibility of the education program. In other places it is done by the unions in apprentice school. The industry claims that the safety of the iron worker who is connecting is improved more by education than by wearing safety belts and lines. The most important area to concentrate on is the new inexperienced worker. They are involved in a high percentage of accidents.

Design for construction safety is a middle ground between the designer and the builder. U.S.A. practice places the responsibility on the contractor. But interaction between the two is important. For tall buildings, important factors for the contractor are analysis for construction loads (material, cranes), the preparation of detailed erection plans, and bracing schemes to stabilize the building in wind. In some parts of the world it appears that more attention is given in the design stage to diminishing construction hazards than in the U.S.A.

Industry safety programs are probably the most extensively developed by the general contractors and by the larger sub-contractors. Safety meetings are the rule in all tall building construction. In the major firms (usually with the best records), the program is specific for the complete spectrum from top management to the laborer. Management is becoming more aware of the costs related to accidents and is becoming more demanding of their people.

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\*Occupational Safety and Health Act, U.S.A. (1971, rev. 1979)



A recent development is the impact that the user or owner can make in selecting a contractor. Most recently in the United States it has become evident that the owner can have a significant impact on the safety of construction by virtue of his ability to choose a "safe contractor". This is especially true in California where each sub-contractor must file a safety record with the state. Owners could well become more demanding. Safety must be a high priority item with them and be incorporated in specifications and in bidding documents.

Finally comes safety consciousness. This subject is receiving increasing attention in U.S. practice. OSHA probably has been a major factor in this as has been the impact of liability insurance. People are simply more safety conscious. The idea continues to grow that safety is important.

What about the trends and future prospects? The construction industry as a whole has been doing better in recent years, the death rate per 100,000 having dropped from 61 in 1970 to 45 in 1980.

As far as tall buildings are concerned, the old "rule" of one death per million dollars of construction (1930's) or "one death per floor" (1900's) has been replaced by one or two deaths per fifty floors or one death per \$200,000,000 or more. The tendency is definitely for an improvement in the safety record.

Why is this? The two main reasons have to do with worker attitude and motivation, and the other is better equipment. Some have suggested that the entry of women into construction has been a positive influence; some say otherwise. There is a general maturing of the work force and this tends to improve the situation. The impact of OSHA is a definite factor. Unions are supportive. With regard to equipment, there is improved hoist design. More frequently there are separate hoists for personnel and for material, and the use of metal deck to replace temporary flooring in steel buildings is an improvement as long as it is properly laid and tacked in place. The requirements for insurance (especially premiums adjusted to safety record) and the promotion of safety by insurance companies is a help.

What can be done to improve construction safety on the job? Among the suggestions that have been made are the following:

- A safety coordinator should be required on each tall building.
- Better adherence to the rules that are already available.
- Safety manuals issued to every new construction worker.
- Better coordination of state and city rules.
- Better enforcement (by OSHA in U.S.A.) of correction of serious hazards.
- Be aware. Don't be complacent about safety. Keep your mind on the job.



- Better housekeeping.
- Public information and re-education campaigns targeted to the worker (blue collar) audience whereby they participate in the suggestions and implement the changes.
- The more regular the building layout created by the architect, the more regular the construction. For example, more flying forms, fewer stick-shored forms.
- Increased use of prefabrication with fewer pieces to connect and less formwork in the field; more work done in the shop.
- Increased municipal budgets for crane and safety inspectors.
- More interaction between designer and contractor on safety. Development of detailed erection schemes.
- Cut down on the noise.
- Improved licensing practice.
- Develop safety glasses that workers will more likely wear on the job, even in hot and humid weather.
- Develop a reliable and convenient-to-use method to determine in-place strength of concrete before forms are removed.

In summary, there is a full spectrum of impacts on the safety of tall buildings during the construction phase. It runs all the way from the governmental agencies (federal, state, regional, and city) to the responsibility of industry as a whole. To unions and their opportunity in connection with training programs and union rules. To the owner and the user of the building who can place requirements on contractors or specifically select safe contractors. To the general contractor himself and his safety programs. To the sub-contractor or erector of the building including top management, supervision, and foreman. To the construction worker himself. To the public who not only need to be careful when they are acting as "sidewalk superintendents" but who also are called upon to support the budgets for their city officials so that there are adequate inspectors on the job.

Of top priority are the training of employees, full responsibility of top management for the safety program, correcting unsafe conditions as they occur, enforcement of the safety program by the regular supervisors, and the use of safety meetings to develop positive safety attitudes.

Some of the above is unique to tall buildings. Some applies to all forms of construction. In order to direct the needed resources towards improving the most urgent (and expensive) aspects of tall building construction safety, better information is required. It is hoped that the efforts of the Tall Building Council and its constructional specialists can provide a future focus in this regard. The costs of accidents and most especially the loss of life and personal injury all need to be reduced.



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