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Safety Assurance Concepts for the Construction of Highrise Buildings

Concepts de sécurité pour la construction de maisons hautes

Sicherheitskonzepte für den Bau von Hochhäusern

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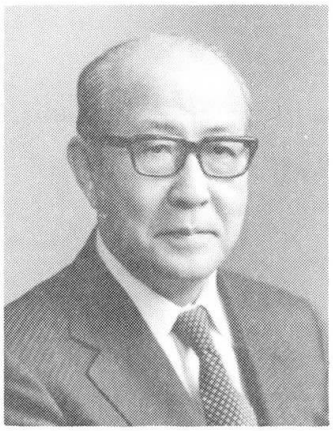


Sei Nikai, born 1911, graduated from Waseda University, Tokyo and obtained doctor's degree in engineering. Sei Nikai, decorated with «Purple Ribbon Medal» by the Japanese Government for his contribution to the development of construction technology for highrise buildings, has held the post of director for Architectural Insitute of Japan.

SUMMARY
The construction of highrise buildings, with the danger of works on high level, requires the establishment a safe working environment and an improved safety awareness of workers. This report shows a technology (climbing, flooring, fireproofing, etc.) adapted to the need of more efficient and safe high rise construction. It indicates the importance of the workers' safety instruction and training as well as the establishment of safety management system.

RESUME
La construction de maisons hautes nécessite l'établissement d'un environnement de travail sûr et la prise de conscience améliorée des problèmes de sécurité par les ouvriers. Ce rapport présente une technologie de construction (montage de grue, construction des dalles, protection contre l'incendie) adaptée aux exigences élevées de sécurité et de productivité. Il indique l'importance d'une instruction et d'un entraînement à la sécurité des ouvriers ainsi qu'à la gestion systématique de la sécurité sur le chantier.

ZUSAMMENFASSUNG
Mit der Gefahr, Arbeiten auf oberen Ebenen auszuführen, erfordert der Bau von Hochhäusern eine sichere Arbeitsumgebung sowie ein besseres Sicherheitsbewusstsein der Arbeiter. Dieser Bericht zeigt ein Bauausführungsverfahren (Klettern, Deckenkonstruktion, Brandschutz usw.) für die an die hohen Anforderungen an Effizienz und Sicherheit passend ist. Auf dem Gebiet der Arbeitssicherheit sind die Ausbildung der Arbeiter und ein systematisches Management von besonderer Bedeutung.

1. INTRODUCTION

Japan being a country with a high incidence of earthquakes previously prohibited the construction of buildings 31 meters or more.

New earthquake resistant structures (flexural structures) and computer-aided techniques for analyzing earthquakes were established and, on the basis of studies on disaster prevention, materials, structures, facilities, and construction, the laws were amended in July 1963, to remove the height limitation and to introduce a new limitation system based on a building-to-ground ratio.

This began the highrise building construction era in Japan. Most of the highrise buildings in Japan are from 30 to 60 storied because of the effective utilization of the limited land area. Highrise buildings in Japan are light weight and rigid and hence benefit from the steel-reinforced structures.

In the wake after the construction of Japan's first highrise building, Kasumigaseki Building (36-storied, built in 1968), for which the author was responsible, over 40 buildings with a height of 100 meters or more have been built throughout the country. This shows the acceptance of highrise buildings among the general public.

The purpose of this paper is to exemplify the current conceptual approaches to safety assurance in the construction of highrise buildings in Japan with primary reference to the author's own ideas.

2. HIGHRISE BUILDINGS CONSTRUCTION PROBLEMS

The construction of highrise buildings involves increased work-loads and engineering complexities associated with their heights and huge scales, which results in lower work efficiency and longer construction terms and required safeguard measures for workers.

To construct a highrise building and have better work efficiency and a shorter construction term, it is essential that the workers move sequentially from lower to upper stories at a prescribed rate of progress. The author calls this constructional approach the "sequential repetition method". This method is of essential importance for efficient construction of highrise buildings.

With the "sequential repetition method", consideration must be given to worker safety during the concurrent execution of works on different floors which is inevitable in such operations as steel erection, flooring, and fireproofing, as illustrated in Figure 1. To establish a safe working environment, the study of proper construction processes in the design stage and coordination of the work schedules are essential.

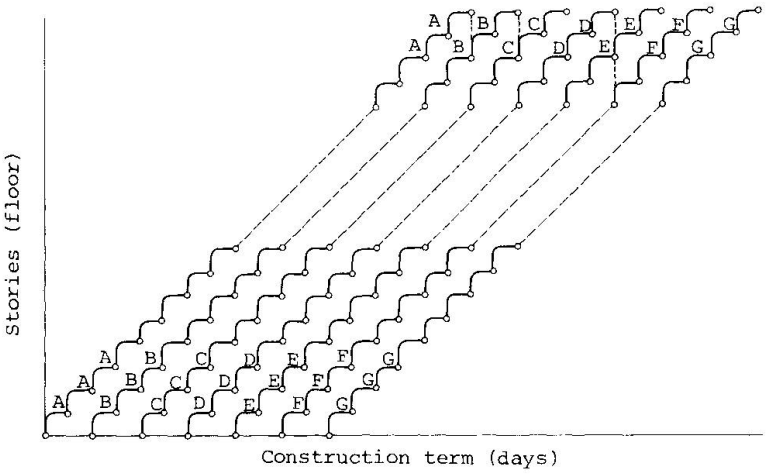


Fig. 1 Sequential Repetition Method

Legends

A: Steel erection works
B: Floorslab works
C: Fireproofing works
D: Curtain wall works
E:
F: } Ceiling and interior finish works
G:

3. SAFE HIGHRISE BUILDING CONSTRUCTION METHODS

3.1 Considerations

To construct a highrise building safely, floorslabs must be installed promptly to provide a working floor, simultaneous with the erection of the steel frame. Hence, the study of a flooring method is a primary consideration to the removal of anxiety of workers who work at high places, protect workers from falling objects, keep workers from falling, and to assure the early commencement of subsequent works. To expedite the erection of the steel frame, use of safe, high-performance tower cranes are indispensable.

Fireproofing works require new methods be sought from a safe and hygienic viewpoint, because the conventional spray method is liable to emit dust and cause dispersion. Temporary lighting must also be considered to enhance worker safety.

3.2 Mast and Bell Portion Dividing Self-Climbing Cranes

High-performance tower cranes are essential equipment in the construction of highrise buildings. If an accident should occur with a tower crane, it could easily develop into a disaster because of the weight of the object being lifted, coupled with the crane's weight.

The safety of the crane is controlled by the Labor Safety and Sanitation Law, Regulations Related To Cranes and Other Equipment, and other regulations. Cranes are also well-equipped with a variety of safety devices.

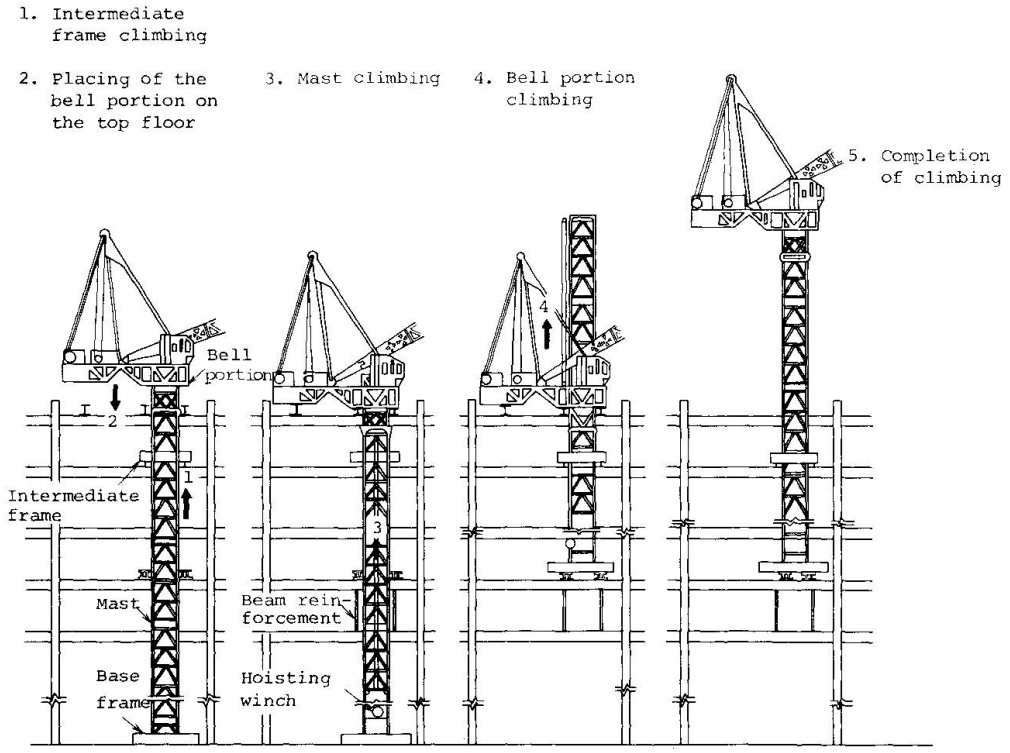
Among all the crane operations involved, climbing is the most hazardous one. Two tower crane climbing methods have been in use: jointed mast climbing method and the crane overall climbing method. With the jointed mast climbing method, the masts stem from under the building hindering that part of the building from subsequent execution. As higher buildings are constructed, more masts are

required, resulting in an undesirable increase in the weight of the crane and in the size of its members.

The overall climbing method poses a safety problem in the lifting a crane weighing from 100 to 150 tons.

To solve these problems, noting that the mast and the bell portion are equal in weight, the author has devised a climbing method in which tower crane is divided into the mast and bell portion, which are then caused to climb separately. This climbing method allows the total climbing weight of the tower crane to be distributed between the mast and the bell portion thereby enabling the climbing operation to be done safely and efficiently in a single day.

With this method, a mast length of only about 30 meters is needed, and, during each climbing operation, the mast is caused to climb only the minimum length of one tier (10 - 15 meters), needed for the erection of framing - and hence assures both safety and economy.



Japanese Patent No. 741370
U.S. Patent No. 3485384

Fig. 2 Self-Climbing Crane

The author has named this climbing method a "Mast and Bell Portion Dividing Self-Climbing Cranes", which is patented in both Japan and the U.S.

3.3 Deck Plates Form Special Floorslabs

As stated above, the floorslab, which is constructed in parallel with the initial steel erection work, should assure simultaneously expediting the safe construction works by promptly providing a horizontal working floor. Hence, the floorslab method has been devised to satisfy the following requirements:

1. To form a solid working floor in the initial stage of construction.

2. To provide safeguards during the concurrent execution of works on different floors.

3. To facilitate erection, and allow simple, safe, repetitious operation in areas where no scaffolding is available.

4. To facilitate execution of subsequent operations.

5. To assure worker safety during construction against wind and other factors associated with operations at heights.

6. To avoid schedule constraints on framing erection works already in progress.

The traditional form method poses the danger of slab material dispersion and falling during the dismantling of forms after concrete placing, and can be harmful to frame erection because of the use of a crane to convert and transport forms. This method also calls for a pipe support period during the concrete curing term, after concrete placing, which is not desirable from the viewpont of the schedule.

Precast concrete slabs can be placed in position at relatively early times but the floor boards cannot be installed without using a tower crane, thus hindering frame erection work.

The author has developed a special deck plate form slab having the advantages of deck plate slabs currently in use in the U.S. and Europe, and is also compatible with Japan's particular conditions.

This slab utilizes the channel cross sections of a deck plate. Reinforcing bars are arranged in the channels in one direction only to reduce reinforcement needs. The deck plate is not treated with fireproofing materials, but has a high resistance to fires for a two hour period, with a minimum thickness of concrete.

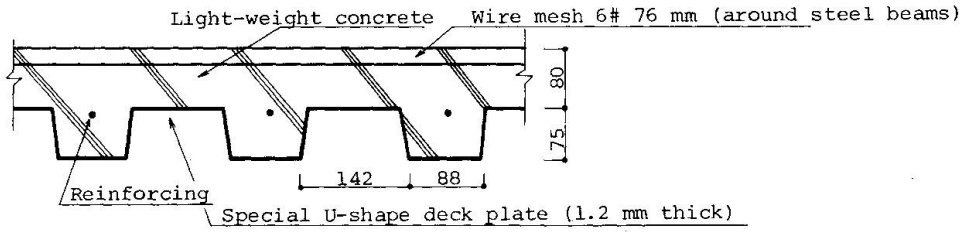


Fig. 3 Special Light-weight Concrete Slab Cross Section

Concurrently with the erection of frame, deck plates are lifted and immediately placed in a predetermined area to form a safety passage way. As soon as the welding of joints and the tightening of high-tensile bolts (H.T.B.) are completed on a floor, the floor is covered with deck plates for safety. Thus, passage ways are always available on the floors (usually 3 to 4 floors) during frame erection and subsequent operations can be commenced on lower floors.

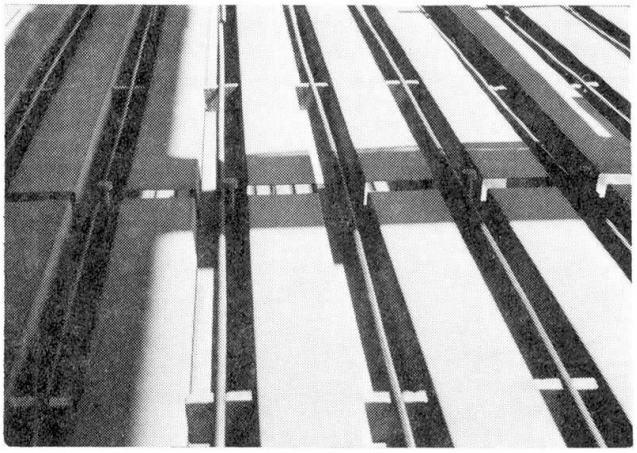


Fig. 4 Floor bar arrangement

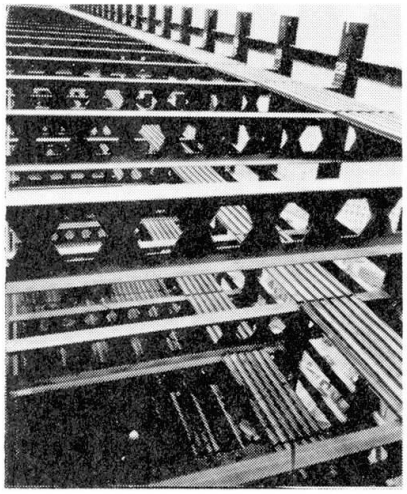


Fig. 5 Temporary passage ways covered with deck plate, for safety

Fig. 6 One-way arrangement of bar and floor duct

3.4 Formed Board Fireproofing

This section depicts an example of a construction process specifically developed to assure the health of workers and to prevent accidents during the construction of highrise buildings.

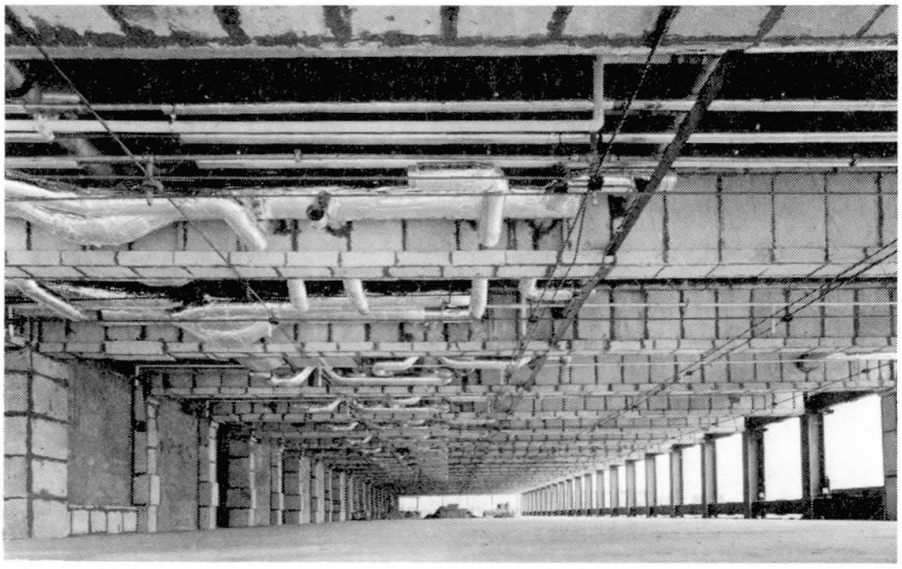
Steel-framed buildings need fireproofing to prevent deterioration of their columns and girders, and the resultant damage to the structures, in times of fires.

When the construction of the Kasumigaseki Building was commenced, the dry spraying process was in use in which fireproofing was accomplished by mixing asbestos and cement, feeding the mixture under pressure, and by further mixing with water at the tip of a spraying nozzle.

This process was feared to be detrimental to the health of spray workers because of the dust raised as well as to the health of the public in case of the dispersion of dust.

The author has developed a new process in which rock wools and cement are prefabricated into formed boards, which are then bonded together on site with a special fireproof adhesive agent. The new process not only precludes the health problems associated with dust emission but also ensures comparatively safe and solid installation of high-quality fireproofing for the exterior of structures.

This fireproofing process is patented in Japan, the U.S. and Australia.



Japanese Patent No. 944120, U.S. Patent No. 3570208, Australian Patent No. 425721

Fig. 7 Formed board fireproofing

3.5 Utilization of Electrical Facilities during Construction

Temporary wiring is a minor part of the construction of any building, but inadvertent wire cuttings or short circuits could cause fires or leak accidents.

Formerly temporary lights were suspended from the ceiling with an exposed network of wires. From a viewpoint of safety, the author has developed an accident prevention method in which wiring or lighting fixtures are installed at an early stage preventing accidents resulting from exposed wires.

A preinstallation process has been developed to enable final lighting fixtures to be installed on a floor prior to finishing its ceiling.

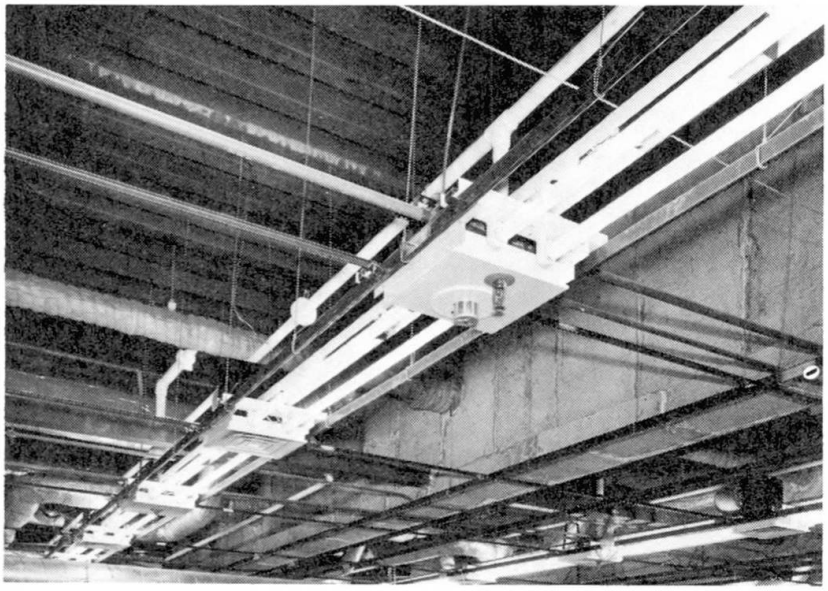


Fig. 8 Preinstallation process

4. SAFETY AND HYGIENE ADMINISTRATION

Improved safety administration, both physical and engineering, as well as the high-level administration technique for enhancing workers' awareness, are essential during the construction of highrise buildings. The following is a summary of these administration techniques.

4.1 Planning and Management of a Reasonable Progress Schedule

To proceed with the work both safely and efficiently, scientific progress management is essential to allow a smooth workflow by avoiding the unreasonable concurrent execution of different jobs on the same floor.

The erection of frame and other operations for highrise buildings are subject to natural constraints such as rain and wind. Thus, these factors need to be statistically considered when drawing up a progress schedule so as to avoid operations under adverse weather conditions.

4.2 Better Floor-to-floor Communication and Coordination

Inadequate protection against falling objects can be quite hazardous during the concurrent execution of jobs on different floors. From a viewpoint of supervisory responsibility, floor-to-floor communication and coordination should be mandatory.

This hazard is particularly pronounced in the construction of highrise buildings, as operations are executed from lower to upper floors in a sequence. In general, deck plates are preinstalled to provide protection against falling objects before the placement of concrete floors, but equipment and elevator shafts, etc. remain hazardous. To avert hazards associated with these shafts, it is imperative to provide complete safeguards against falling objects at intervals of several floors and to avoid the concurrent execution of shaft operations on different floors through increased communication and coordination between the floors.

4.3 Complete Transmission of Safety Instructions

To increase workers' awareness of safety, important instructions regarding each operation must be transmitted to the workers prior to the commencement of that operation. It is effective to enter safety instructions in the work manuals.

4.4 Establishment of a Safety and Hygiene Administration System

Highrise building construction involves more workers and work management efforts than that of general construction works. The workers tend to depend on others for safety or to regard the safety as the exclusive duty of safety administrators or other designated personnel.

At the time of site-in, each worker in charge of a specific operation must be familiarized with safety administration items in accordance with the Labor Safety and Hygiene Law.

Highrise building construction also calls for use of special construction machinery and equipment and for mechanical inspection and maintenance. It is essential to have a job responsibilities plan to be able to service all machinery without delay after bad weather, such as strong winds, heavy rains, and heavy snowfalls. It is also important to clearly define responsibility and the system of maintenance for safety facilities, such as handrails, nets for covering concrete during curing period, and fall prevention nets.

4.5 Enhancement of Safety Awareness

Enhanced safety awareness is extremely important in all construction works. Workers engaged in the construction of a highrise building, however, cannot be attentive to all safety details because of the many control floors involved. Each worker should be individually educated to be responsible for his own ensuring safety and to prevent careless acts from jeopardizing others.

Enhanced safety awareness can be accomplished by holding general safety meetings, safety morning meetings, and tool box meetings periodically. Table 1 gives safety event examples.

Table 1 Safety Events

	Event	Description
Conducted daily	Workshop physical exercises	Participated in by all workers.
	Safety morning meeting	Participated in by all workers.
	TBM (Tool box meeting)	Held for each job category and group; hazard prediction activity
	Startup inspection	Performed for each job category and group; leak protection
	Safety and hygiene patrol	Safety and hygiene supervisor, administrator, controllers, and other personnel responsible for safey
	Safety progress meeting	Job descriptions, predictable hazards, and countermeasures, issuing of instructions
	Cleanliness and cleaning	Five-minute clearing before conclusion of work
	Firemens' meeting	Communication and coordination between foremen (between subcontractors)
Conducted weekly	Machinery and vehicle inspection day	Authorized operators, voluntary inspection status, permission to operate
	Temporary facilities inspection day	Sand guards, material yards, drainage facilities
	Simultaneous cleaning day	Offices, lodgings, rest rooms, in and out of sites
	Safety progress meeting	Job descriptions, predictable hazards and countermeasures

	Event	Description
Conducted monthly	Safety and hygiene committee	Discussion of basic guidelines on safety and hygiene administration
	Safety and hygiene conference	Summoning of all subcontractors' safety and hygiene controllers, discussion and adoption
	Special safety day	Presentation of accident case studies and of safety lectures
	General safety meeting	Enhancement of workers' safety awareness, explanation of monthly progress, setting of monthly safety goals
	Electrical and mechanical facilities inspection day	Power receiving facilities, insulation resistance testing, leak protection, hazard marking
	Safety and hygiene related documentation inspection day	Safety progress meeting, work instructions, safety and hygiene committee, safety and hygiene conference, safety education, and so on
	Safety progress meeting	Job descriptions, predictable hazards, and countermeasures
Conducted as needed	New worker education	Education and training of new workers in field regulations, work routines, and safety practice based on field workbooks and new worker guidebooks
	Safety and hygiene education	Hazardous jobs, job description, etc.
	Medical checkups	Routine and special checkups
	Fire prevention and evacuation	Training in fire prevention, rescue, evacuation, and so on
	Traffic accident prevention	Operation scheduling, in-site operation, access routing, arrangement of conductors

5. CONCLUSION

Those engaged in highrise building construction are responsible for safety by overcoming difficulties associated with the height problem. The assurance of safety can turn a construction site into an attractive workshop and make for increased efficiency.

Now that construction of highrise buildings has taken root in Japan to play a leading role in urban development, the number of highrise buildings tends to increase on a steady base. We are all committed to the prevention of accidents by researching highrise building construction safety.

It is author's conviction that these studies will also be applicable to ordinary construction works and to help establish greater safety on the construction sites where many factors exist for accidents.

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