Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 44 (1983)

Rubrik: Part II

Health and Safety in Construction

Santé et sécurité dans la construction

Gesundheit und Sicherheit im Bauwesen

Lodewijk P. SIKKEL
Prof. of Construction Management
University of Technology
Eindhoven, The Netherlands

Born in 1924. M.Sc. Civil Engineering, 1951 University of Technology Delft; 10 years Dutch Railways; 4 years municipality Amsterdam; 9 years director contracting firm, Professor since 1974.

SUMMARY
«Healty and Safety» proves to be a great problem in the construction industry all over the world. Statistics give only a view on the number of accidents, not on the unsafe situations during construction; the figures given by different countries are often unreliable, they are not comparable. Safety-planning and Risk-analysis should be used as a tool of safety management. This report is a summary of both the author's paper presented at the Seminar in Tokyo and the papers presented by the Japanese experts on that occasion.

RESUME
Le thème «santé et sécurité» est un grand problème dans l'industrie de la construction dans le monde entier. Les statistiques ne donne qu'une vue du nombre des accidents mais ne parlent pas des situations dangereuses pendant la construction. Des valeurs données dans différents pays sont souvent peu sûres et ne sont pas comparables. Le concept de sécurité et l'analyse du risque devraient être employés comme moyen de gestion de la sécurité. Ce rapport est une version condensée de l'article «Santé et sécurité dans l'industrie du bâtiment», présenté par l'auteur lors du séminaire AIPC à Tokyo et des différents articles présentés par les experts japonais à cette occasion.

ZUSAMMENFASSUNG
Das Thema «Gesundheit und Sicherheit» ist ein grosses Problem für die Bauindustrie auf der ganzen Welt. Die Statistiken erfassen bloss die Anzahl Unfälle, sprechen aber nicht von den gefährlichen Situationen während der Bauausführung. Werte, die verschiedene Länder abgeben, sind oft nur wenig sicher und auch nicht vergleichbar. Sicherheitskonzepte und -analyse sollen als Werkzeug für die Behandlung von Sicherheitsproblemen dienen. Dieser Bericht ist eine zusammengefasste Version des Artikels «Gesundheit und Sicherheit im Bauwesen», der vom Autor anlässlich des IVBH Seminars in Tokio vorgetragen wurde, und der verschiedenen von japanischen Experten bei dieser Gelegenheit vorgetragenen Artikel.

1. HEALTH AND SAFETY

1.1 Safety

Perhaps it is good to start with some slogans, we can meet when we are studying this subject: Health and Safety in Construction:

- "Safety is no Accident ....!"
- "Safety is up to you ....!"
- "Don't be half safe ....!"
- "Be alert .... stay alive ...!"

Are those slogans 'lip-services' or real accident preventions? We can not solve our problems with only bringing slogans to the building-sites!

Safety must be a basis-component in the management-philosophy of our company, in our work on the sites, in our cooperation with partners in the construction process.

1.2 Is safety a problem?

When we think about this subject, we soon shall realize that we have a great problem: the construction of building and civil works in far more unsafe than we are willing to know.

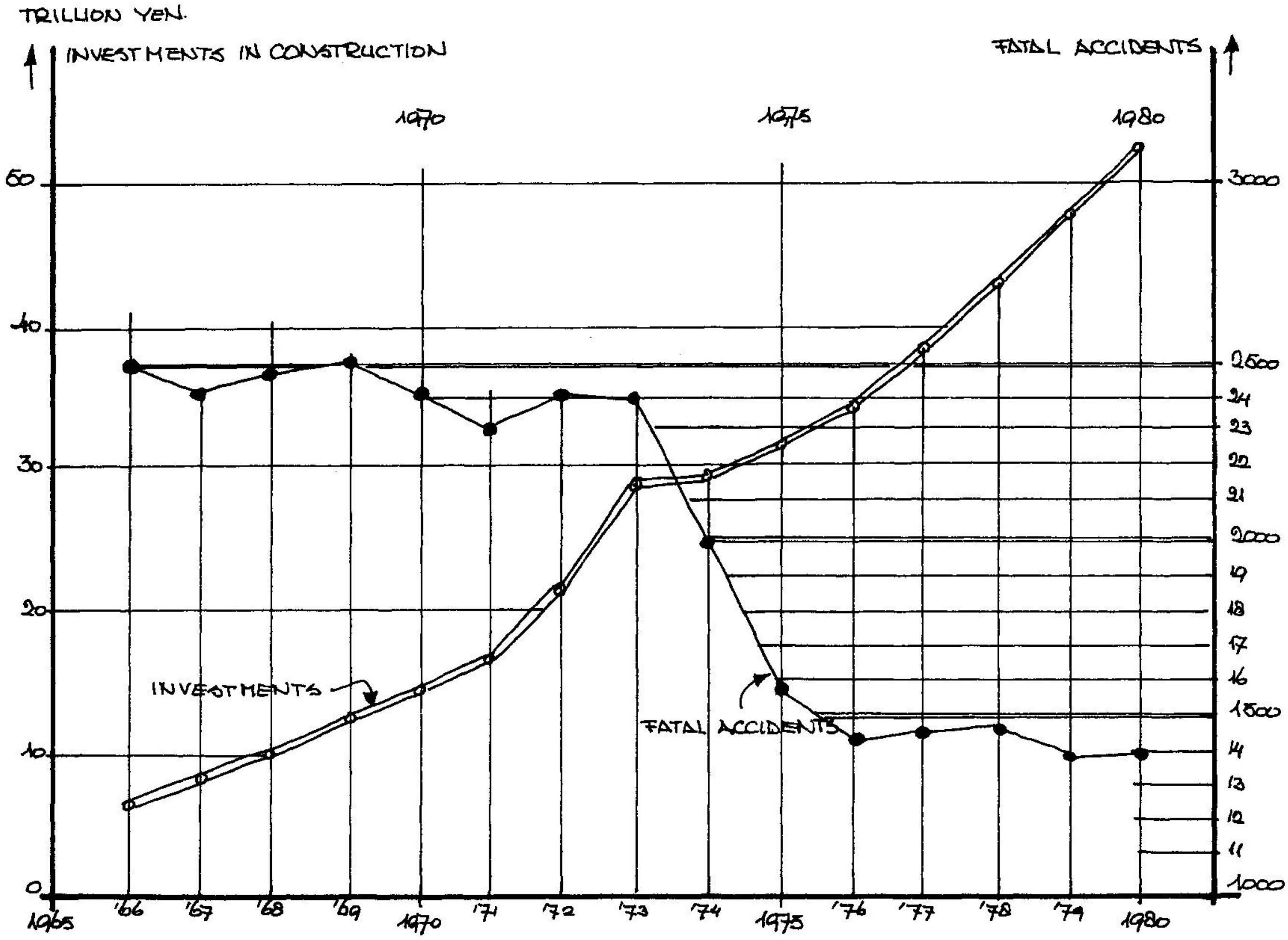


Fig. 1 Trends of construction investments and fatal accidents at work, Japan (Paper Mr. Mino)

Mr. Mino showed us in his paper a picture, which gives a relation between the investments in construction in Japan and the amount of fatal accidents, during the period 1966-1980.
We see the investments raise from about 0.75 x 10 trillion Yen to over 5 x 10 trillion Yen and a decrease of fatal accidents from about 2500 a year to some 1400 a year. With a decrease from + 2400 to + 1600 fatal accidents during 1973-1975, the period in which new legislation on occupational health became into action (fig. 1).

Also Mr. Itoh showed some graphs, in which he gave an impression about the fatal accidents in the construction industry in relation to those in the whole industry in Japan (fig. 2): we see that the construction industry takes + 40% of all fatal accidents in the whole industry! He showed us also, the lines which give us the rate of serious (inclusive fatal) accidents to every 10,000 workers in industry: we see (fig. 3) that this rate for our construction industry is 2.5 times higher than in the total industry.

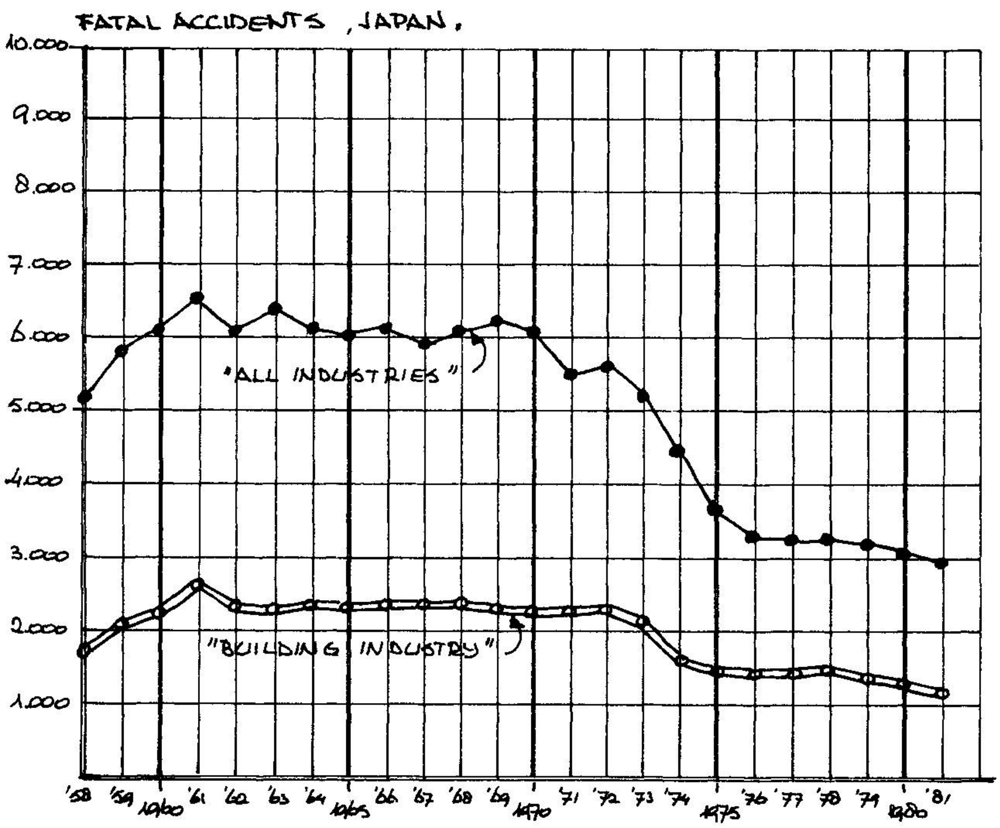


Fig. 2: Fatal accidents in all industries and in the construction industry, Japan (Paper Mr. Itoh)

Seeing those pictures and reading their papers, we can conclude that Japan has a problem when we talk about safety in construction work.

But it is not only Japan, that has this problem: all over the world we meet such terrible figures!

In figure 4, I give some figures from Europe: in some years between 1977 and 1981.
The figures gave some impression, but we cannot compare them. Every country has its own way to make their statistical reports; even 'fatal' gives figures which are not quite correct: when death occurs after some more months, this is sometimes not counted to the fatal accidents! Also the number of accidents often differ, because of the fact that in some countries the first day of absency after an accident is already counted and in other countries thay start to count after 4 days or more.

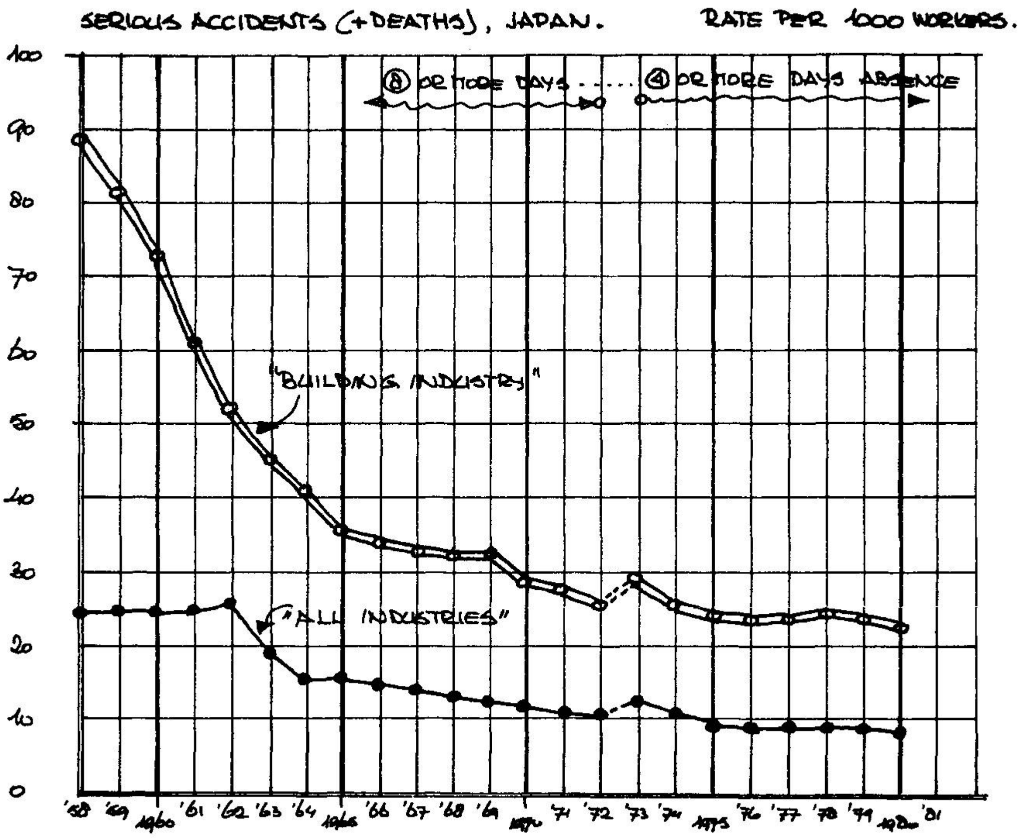


Fig. 3: Serious accidents, incl. fatal accidents, Japan; rate to every 1000 workers (Paper Mr. Itoh).

IN ONE YEAR BETWEEN 1977-1981	WORKERS:	ACCIDENTS:	FATAL:
NETHERLANDS:	± 350.000	± 25.000	30
JAPAN:	± 4.000.000	± 100.000	1200
GERMANY:	± 2.000.000	± 250.000	390
SWISS:	± 320.000	± 82.000	86
ENGLAND:	?	± 30.000	127

Fig. 4: Some data about unsafety ....

And from Scandinavia I got figures from which the writer told me to multiply them three times to get some idea about the real figures .....!

So we can conclude that we have a great problem in our industry and that this problem is perhaps still bigger than we know now!

1,3 Safety and Costs

When we read in literature about chapters of our problem field, we always meet the discussions about safety and costs.

Let us try to think about these relations in the way I put it down in figure 5:
When we speak about construction we always have to do with certain working situations. And we all know that during construction on the sites and in our manufactories we meet certain dangerous situations.

Out of these dangerous situations incidents and accidents occur and we try to work in a safe(r) way by making prevention programs. Both with management and the workers we have to reckon.
Incidents and accidents originate certain costs, counted in a direct and in an indirect way.
Also safety-measures will ask certain costs, certain investments. The less safety measures the more accidents can occur: the total costs will be high.
More safety-measures will give less accident costs but more safety measure costs. We think the total cost will decrease.

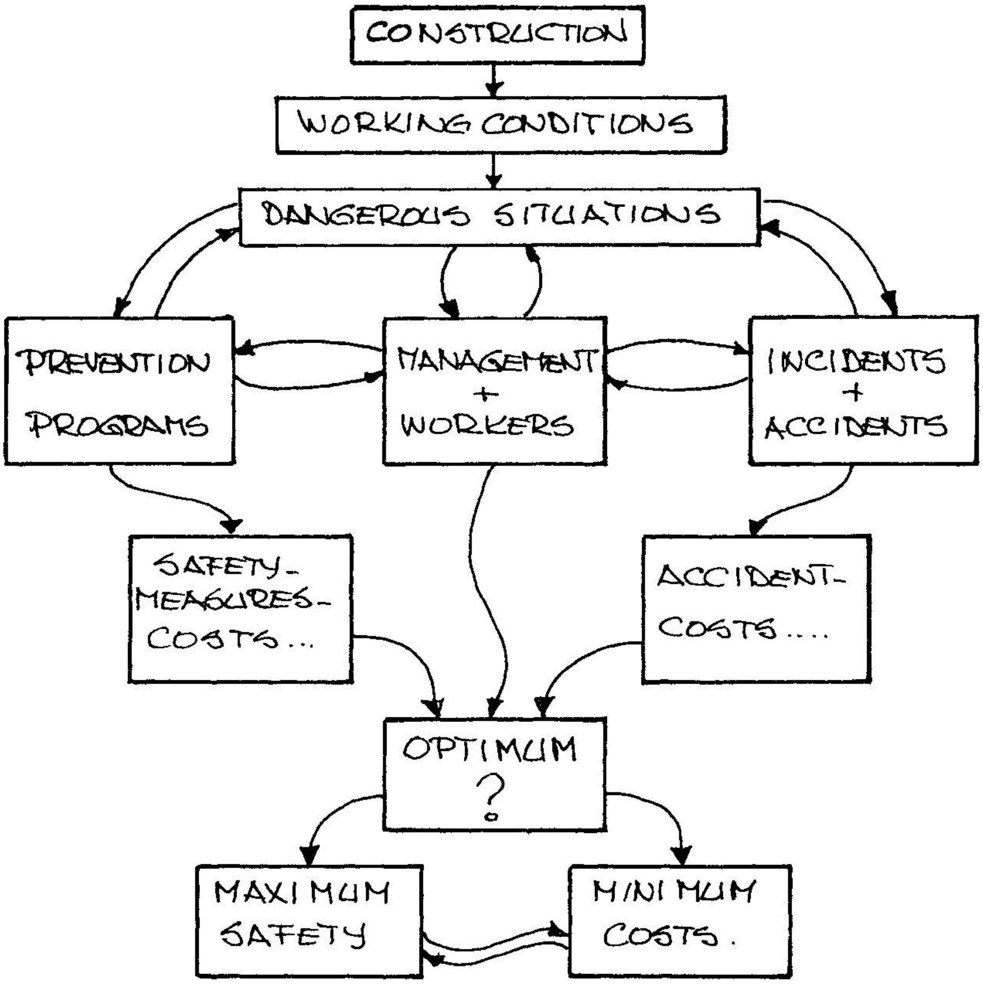


Fig. 5: Relations between safety and costs

Can we talk about some optimum?

- Perhaps we have minimum costs, with a certain amount of safety-measure-costs.
- Is there a possibility of maximum safety?

In figure 6, we put this philosophy in a graph.

- Line A is the decreasing cost-line of accidents
- Line B is the increasing cost-line of safety-measures
- Line T is the combination: total A + B costs.

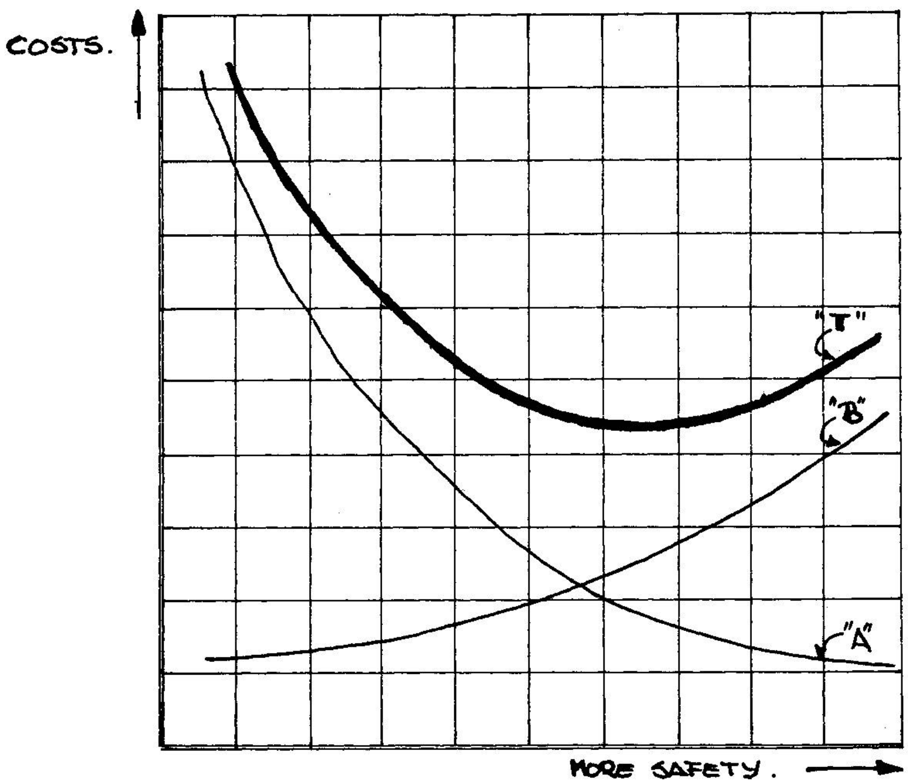


Fig. 6: Safety- and accidents-costs

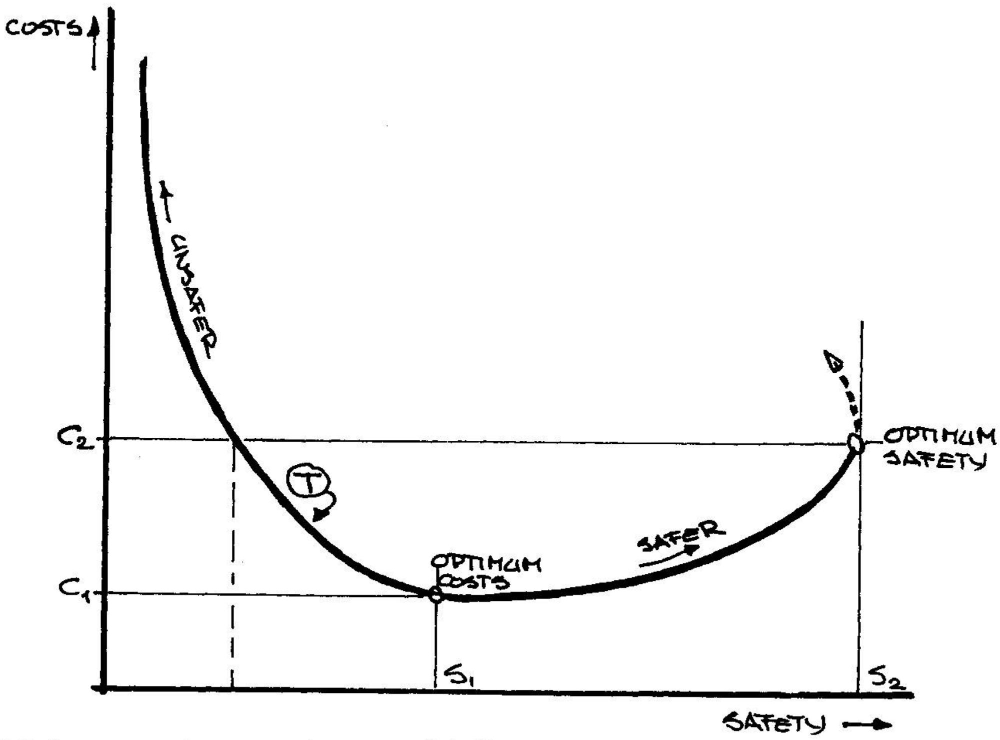


Fig. 7: Minimum costs or maximum safety?

In figure 7, we try to bring in more safety, till we reach the theoretical point of maximum-safety, when we have past the point of minimum costs. There is a question: what happens after maximum safety? People on the sites says: to much safety-measures give again more chances for accidents ....! But this is never proved by any research-study, as far as I can find out!

In figure 8 we let see that this curve will be different for each new building site: every construction work has his own problems, also in the field of health and safety conditions.

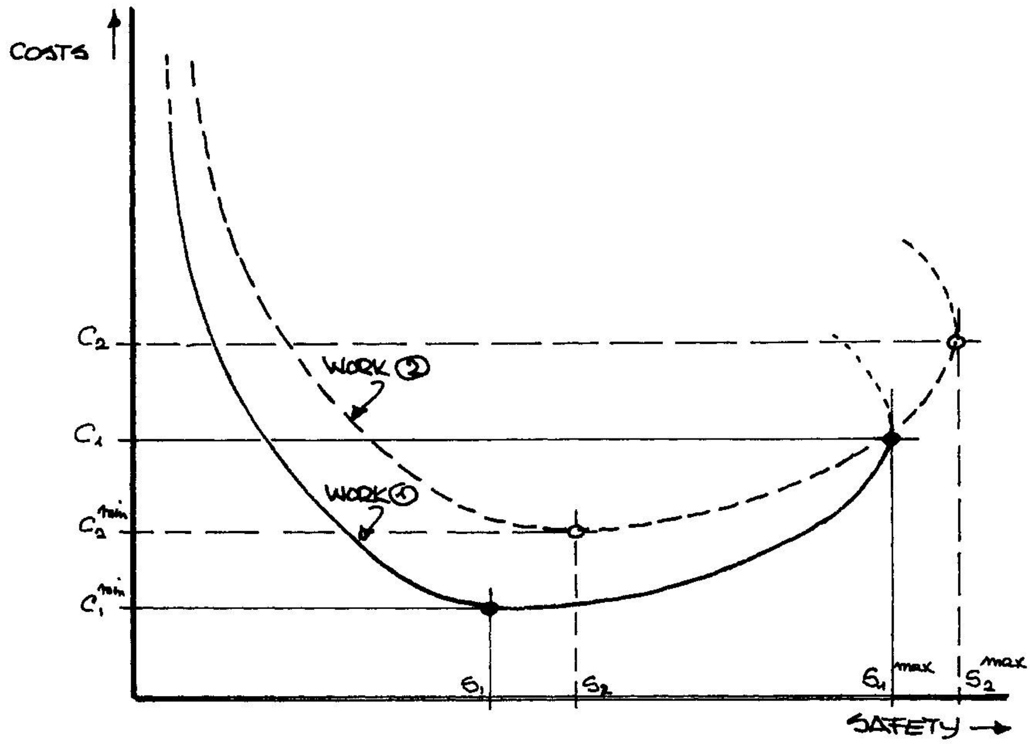


Fig. 8: Every construction site will have his own safety conditions

2. SAFE AND UNSAFE SITUATIONS

2.1 Can we foresee?

We state that there is no safe or unsafe situation in an absolute way! And we wish to say that prevention is only possible when we can foresee the unsafe situations, the unsafe working circumstances, the unsafe actions of the workers and of management.

We shall always have to weigh the chance of occurance of such unsafe circumstances. And we can do that better when we have our own experiences, when the extent in which we will be remembered to such a possibility counts, or when the imaginativeness of some kind of possible accident consists.
However, it will be extremely difficult to prevent those accidents, which never have passed before.

2.2 Backgrounds of accidents

Every accident therefore will have some background, some environment in which it may occur.

We define an accident as: A sudden default of an availability, caused by an unattended disturbance of the usual course of events, or of the fixed way of working.
These courses could be placed under the titles of: wrong methods, wrong means, wrong actions, poor working climate, poor organization, wrong mentality.
And in most of these causes we have to think in terms of 'poor management'.

2.3 Accident Statistics

When we see all the figures in the different accident statictics, we ask ourselves: why do we make these statistics? Do we really use them to make safer situations? Or are they only used for the calculation of the insurance-rates?

For what we see is just a very small part of all unsafe situations: only those unsafe situations which brought us an accident in some way or another. I wish to speak here of the 'Ice-berg of unsafety' and about all the near-accidents within unsafe situations (fig. 9).

Talking about 'Health and Safety in Construction' we have to speak about all unsafe situations; perhaps there are ten times more unsafe situations than we can count as those who came to an accident.

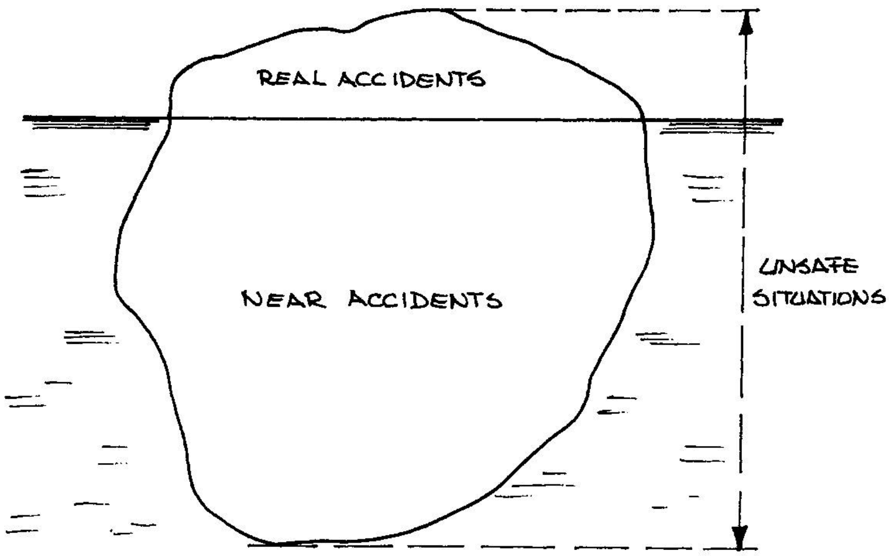


Fig. 9: The 'Ice-berg' of unsafety

2.4 Factors of influence

From American literature I bring here the factors of influence, which may cause unsafe situations and sometimes accidents.
In figure 10 we can read that each worker on the building site has some factors which cannot be influenced and some factors which can be influenced. The first factors come most from his own environment, the second come from this special job on that special site. And suddenly there comes that accident: why just now, on that very moment? Why come some unsafe situations never to an accident, why do some it now?

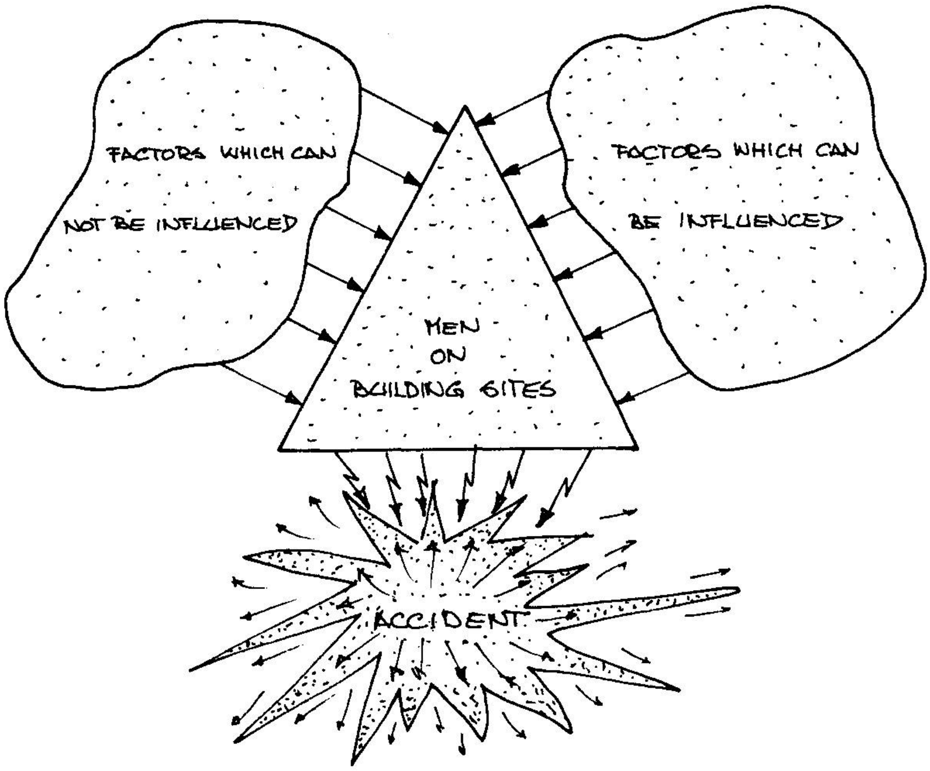


Fig. 10: Factors of influence

2.5 Sudden or slow actions?

Speaking about accidents, as a quick, a sudden default, which brings us damages and injuries, we forget that through certain unsafe working situations or actions our health can be destroyed by poison, radiation, noise, stress, ... etc. These are no sudden actions, but very slow actions and they bring the damages in our body after several years.
So our study field is much broader than only 'the accidents': it includes unsafety in its totality.

2.6 Ratios

Health and Safety belong to eachother: So if we try to think in term of ratios, we should think in:
- Accident ratios

and in:
- Sickness ratios.

All ratios used in different countries look like each-other, but they all differ in one way or another. As I said before: we cannot compare them.
The accident ratios are calculated in two ways:
- Accident Frequency (AF)

and
- Accident Heaviness (AH) or: Accident Severity.

I suggest an international ratio; which is defined:

$$A.F. = \frac{\text{number of reported accidents}}{\text{number of men years}} \times 100\ (=\%)$$

$$A.H. = \frac{\text{number of reported lost days}}{\text{total worker days/year}} \times 100\ (=\%)$$

In the same way we could count with sickness-ratios:
- Sickness Frequency = S.F.

and
- Sickness Heaviness (or Severiness) = S.H.

which could be calculated as:

$$S.F. = \frac{\text{number of reported sick-cases}}{\text{number of men years}} \times 100\ (=\%)$$

$$S.H. = \frac{\text{number of reported lost days}}{\text{number of worker days/year}} \times 100\ (=\%)$$

Still there remains the questions of:
- Reported accidents: how do we get the good figures?
- Reported lost days: in my opinion the first day of absency is already a lost day!
- The question of heaviness: in some countries they count extra lost days when the accident is less or more heavy. Of course gives this a certain information of the heaviness of such an accident, but in my opinion is it not right to do so in these ratios. I suggest to bring this information in another way.

2.7 Case

As a case study, I give the ratios as defined above of The Netherlands in round figures:

suppose:	Men years =	350,000	(years)
	Men days =	77,000,000	(days)
sickness	Cases =	485,000	(number)
	Lost days =	9,650,000	(days)
Accidents	Cases =	18,000	(number)
	Lost days =	450,000	(days)

Ratios:

HEALTH $S.F. = \frac{485{,}000}{350{,}000} \times 100 = 138.57\%$

$S.H. = \frac{9{,}650{,}000}{77{,}000{,}000} \times 100 = 12.53\%$

SAFETY $A.F. = \frac{18{,}000}{350{,}000} \times 100 = 5.14\%$

$A.H. = \frac{450{,}000}{77{,}000{,}000} \times 100 = 0.58\%$

3. THE SAFETY CHAIN

3.1 Chain of events

From Swiss we learned a lot from the "Safety chain". This means that safety consists as long all parts of a chain of events are held. But in each part we find difficulties, which bring us into certain unsafe situations (see fig. 11).

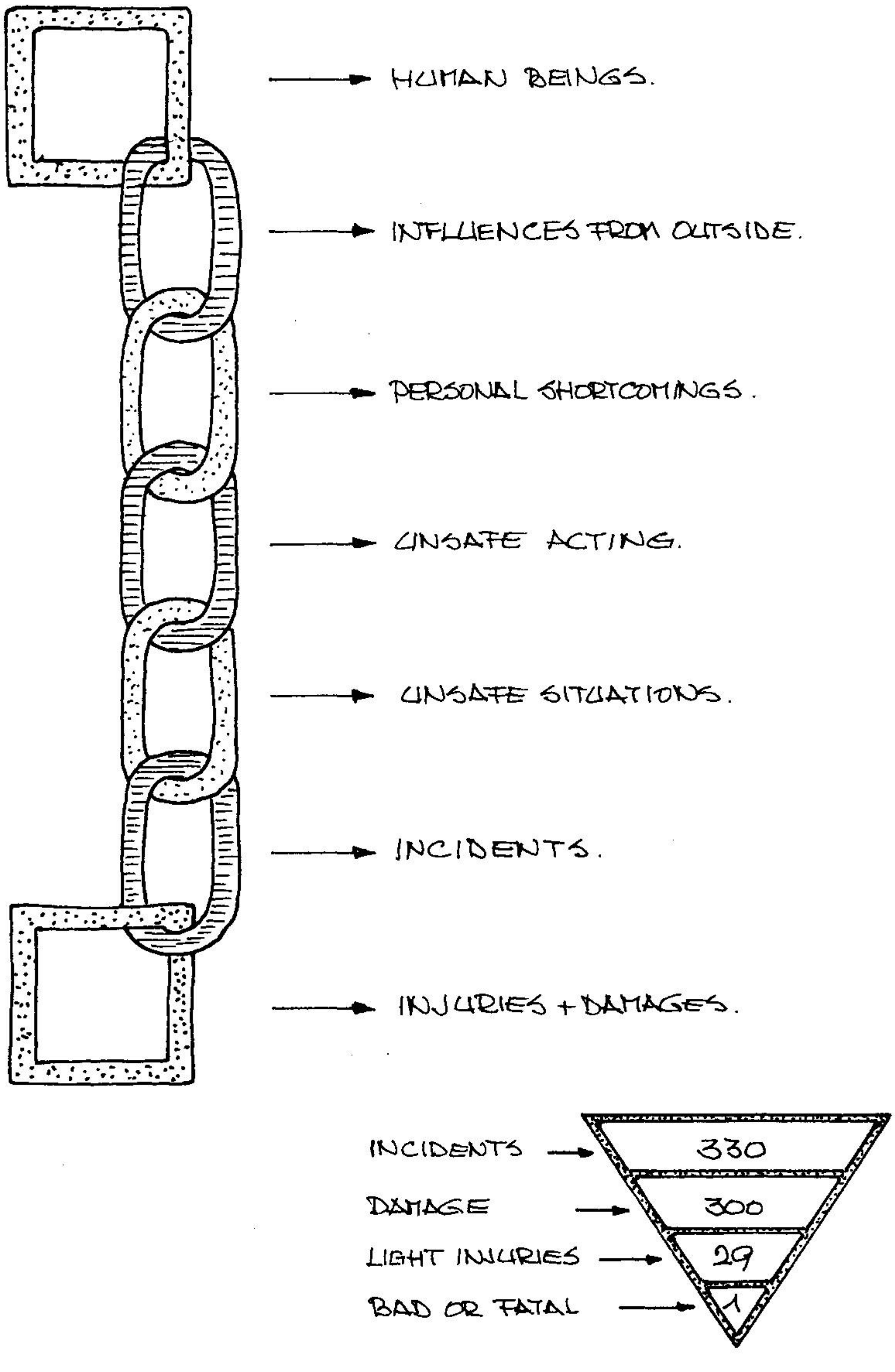


Fig. 11: Safety-chain

Every safety-chain starts with the Human-beings, it ends at last with injuries and damages. In between we meet different unsafe situations. We can bring them into groups of specialities. For instance we have to count with:

- influences from outside as: social -, family -, wheather- , ... etc. conditions
- personal shortcomings, as: not knowing, not capable to do some kind of work, not wishing to do it, wrong mentality
- unsafe actions, as:
  . unqualified activities
  . unsafe place of work
  . safety devices put out of operation
  . use of unadequate equipment
  . unsafe loading or unloading, lifting, etc.
  . unsafe working conditions, positions, circumstances
  . unsafe way of joining materials, prefabrikated elements
  . unsafe working near, on and with moving equipment
  . all kind of disturbances in the work
  . not using personal protection.

Further we meet the unsafe situations, which often can be brought back to management: we sum up:

. poor working organization
. insufficient protection
. unsafe working sites
. unsafe use of equipment
. unsafe ventilation conditions
. vibrations
. noise
. unsafe clothes, inadequate personel protections
. wrong mentality.

Then come the special events, which can bring us the incidents and accidents, with damages and injuries.

In Swiss they say that on 330 events, 300 give 'only' damages, 29 bring light injuries, 1 of those events brings bad injuries or death.

3.2 Management

What has Management to do with this?
We mention:
. Stop unsafe actions
. Investigate each unsafe situation
. Give more information and instruction
. Motivate men to do the job in a safe way
. Abolish an unsafe situation at the source
. Take protection measures
. Give on the site warnings on dangerous places through signals, colours, boards, inspections
. Give serious warnings to labourers and prosecute if necessary.

And Management has to know that it is better to take actions beforehand, than reaction afterwards. That means also: Provide safety-programs.

4. SAFETY CONCEPTS IN JAPANESE BUILDING INDUSTRY

Mr. Mino of Suimoto Construction Co, Ltd., brought us a paper handling this subject. He learned us that "safety-first" should be the starting point of all Construction Planning. He showed us the graph as I gave already in figure 1, and he explained us the change of thinking in Japan.
Till 1960, the Construction Industry was still thinking in terms of "Accident Norms". This means that but few people were concerned when accidents stayed below that 'norms'.
After 1960, the new way of work became the thinking in "safety-concepts".

Due to direct actions taken by the M.O.C. (Ministry of Construction), the Construction Industry became more aware of the neccessity of safe working-conditions. So the different kind of work brought with it the classification of contractors into several grades of capacities. And when accidents will occur, due to poor safety management, MOC do suspend the qualification of the contractor during some period of 3 - 9 months.

Mr. Mino told us also that the costs of Health and Safety measures are now ± 2.9% of the total contract sum.

5. MEASURES FOR PREVENTION OF LABER ACCIDENTS IN CONSTRUCTION INDUSTRY AND SAFETY

5.1 Develop a control system

Mr. Itoh, of the Ministry of Labour of Japan, says in his paper that the labour accidents in Japanese Construction Industry have decreased due to the efforts of all partners concerned.

However, he says, there are still more than 100,000 serious accidents and more than 1200 fatal accidents, on the labour force of ± 4.000,000 in our industry. That means 3 deaths, to 250 serious injuries, to every 10,000 men years. This rate of accidents is much higher than in all other industries.
Therefore his first conclusion is: it is necessary to develop a good control system in regard of Health and Safety.

5.2 Ratio

Mr. Itoh gives us the Japanese definitions of:

$$\text{Frequency Rate} = \frac{\text{serious accidents (+ deaths)}}{\text{total working hours}} \times 10^6$$

and of:

$$\text{Severity Rate} = \frac{\text{lost working days}}{\text{total working hours}} \times 10^3$$

The lost working days are counted as: 300/365 x calendar days of absency.

And he mentiones that for serious accidents:
- death is counted for 7500 days!
- other injuries with physical handicaps are counted for 50, 100, 200, 600, 1000, 1500, ..., 7500 days!

As I already told, I disagree myself with this way of counting injuries as extra lost working days, although it gives some information about the severines.

5.3 Divisions

Mr. Itoh gives us also a division of injured workers in some special kind of work in our industry.

injured workers	1970		1975		1978	
	total	±%	total	±%	total	±%
civil work	39,775	40	42,833	44	45,546	38
building work	48,338	48	48,200	48	64,086	54
equipment work	12,127	12	8,373	8	8,936	9
total	100,240	100	99,406	100	118,568	100
deaths	2,430	1.41	1,582	1.63	1,583	1.75

And for 1981 he finds: fatal accidents: 1173 trough following causes:

causes	number	%
falling	425	36.2
breakdown	91	7.8
collapse	97	8.3
machinery	425	36.2
electricity	48	4.1
fire, explosion	18	1.5
handling	10	0.9
others	59	5.0
total	1,173	100

5.4 Safety consciousness

At last he pleads for a safety consciousness which starts alreay in the planning phase. Therefore he askes for meetings with the official authorities of Public Works, to get a brief for the safety programs of the contractor.
The Ministry therefore give some guidelines and do examinate the safety-plans of these contractors before the work can start.

Further measurements are:
- The increase of safety of machinery
- Promotion of safety and health education
- Encouragement of voluntary prevention of accidents
- Research and development in the field of safety and health.

6. STOCHASTICAL ANALYSES OF OCCUPATIONAL ACCIDENTS AND ITS APPLICATION TO THE SAFETY PROBLEMS

6.1 Feedback from statistics

Mr. Hanayasu of the Research Institute of Industrial Safety started with the remark that about 30% of all accidents in Japanese industry, occur in the construction-industry and about 40% of all fatal accidents in industry must be counted in our construction industry. He askes himself and us: why? Is it a combination of the problems of management, the working conditions, the environment on the sites, the system of employment in the construction industry?

He states than that safety-management on each construction site would be different from other sites and from the type of work, it should be related to the site characteristics.
Because safety management seems to be difficult, he tries to find a feed back from the statistics of occured accidents to the safety performances. His paper prescribes in detail:

1. the Accident Frequency distribution of occurance
2. a stochastical analysis of occupational accidents
3. its application to the safety-problem.

with the purpose to give an answer on the question: Can we measure the safety performance in our working sites?

6.2 Zero Accident Campaign?

Starting with the accident-frequency rates, he studies on the fluctuating intervals in time between those accidents. He seeks for a useful yardstick to give expression in the field of the safety-performance on that special site, or in some construction firm.

He wants to use this yardstick as a tool of management, for planning a target for non-occurance of accidents in a certain chosen period: to avoid accidents to be taken place. So it could be possible to start a special 'Zero-Accident-Campaign'.

6.3 Study-method

Mr. Hanayasu prescribes his study within the following steps:
- Look at the occupational accidents at random in time, then it can be proved that the Accident Frequency Rate in a fixed time-interval has a Poisson-distribution.
- Look at the time intervals between the successive accidents and find now an exponentional distribution
- This exponentional distribution can be useful for safety-performance evaluation
- The probability of occurance of an accident at a particular time can now be calculated.

The conclusions are now:
- The method can be used to find out significant changes in accident situations during succeeding intervals
- The time-interval-studies can be used as a valuable yardstock for safety-analysis.

6.4 Something new!

We think this paper brings us something that is quite new in our safety and health-studies and it is worthwhile to go further with this part of our problem-field.

7. ACCIDENT PREVENTION BY MECHANISATION OF ACTIVITIES AND OF IMPROVEMENT OF EQUIPMENT

7.1 Start with cause-analysis

The paper of Mr. Miyazaki of Kaweda Industries, Inc, started with the analysis of some causes of fatal accidents in our construction industry.

So he mentioned that:
- Falling of workers causes 37% of all fatal accidents
- Falling of objects causes 6% of all fata accidents.

So 43% of all fatal accidents could be eliminated through replacing of labourers-work through machines.

And further he stated that 30% of all accidents to death are caused by:
- Defects of equipment
- Mis-manipulation of machines.

So improvement of equipment will serve health and safety in our industry.

7.2 Possible solutions

And he worked this out in his paper, when he looked to:

- Hazards in the job itself, which can been lowered through:
  - Mechanization
  - Improvement of machines
  - Central controled operations
  - Remote control of operations
  - Improvement of the working conditions
  - Symplification of the work itself
  - Manipulations with big building parts.

- Hazardous working places, which can be bettered through:
  - Prefabrication and pre-assembling at safe places
  - Strenthening and making safe of working sites
  - Remote control.

8. SAFETY PLANNING AND RISK ANALYSIS

8.1 MORT-system

In our workshop in Zurich, April 1982, we learned about the System MORT, which stands for Management Oversight and Risk Tree. This system comes from USA and was developed by W.G. Johnson in 1970 - 1973, and adapted to the construction industry by Rudolf Frei (Swiss).

Every human action brings with it some risk. Every safety protection measure and every safety program can be put out of action by men. Some risks are unpredictable; other risks are taken wilfully, because of the fact the troubles of removing the danger stands in no proportion to the persued safe situation.

8.2 Fail chances

MORT gives an idealized model of a safety-system build up from the fail chance theories and it analyses the safety system. Therefore a system should be defined as a methodological order of interdependent components, which together or alone, fulfill a function or a task in the whole, within certain circumstances and within a certain span of time.
A system also is a dynamic set of data, which alter in course of time.

In a perfect system, all components will work in such a way that they give a contribution to the total sets of goals.
In any system that does not work in a perfect way, we can meet less or more failures. Therefore we can prescribe a failure as: every factor which gives no contribution to some given goal. Failures therefore can lead to unsafe situations.

The goal of a safety program is to give a way of thinking through which the chance of the appearance of identifiable level. So we have the possibility to keep unsafe situations under control in a systematical way.

8.3 A tool of Management

So using MORT as a tool of safety-management we have a cheap, feasible method which follows step by step our management-decisions. It is nothing new, it is not theoretical, but it is a system that is tried out ...., is already used......., is not time devouring. The whole system consists of endeavoured concepts and it avoids something.
When we are thinking about damages, losses, problems, unsafe work, unsafe situations, we can think about calculated risks and about faults and wrong acting. These faults and wrong activities can lead to accidents.
Why do we come into such incidents? Could it be an output of failures in our management system? Could it be in management itself, or in the kind of risk analyses, the follow up of measurement, the policy the policy in the organization?

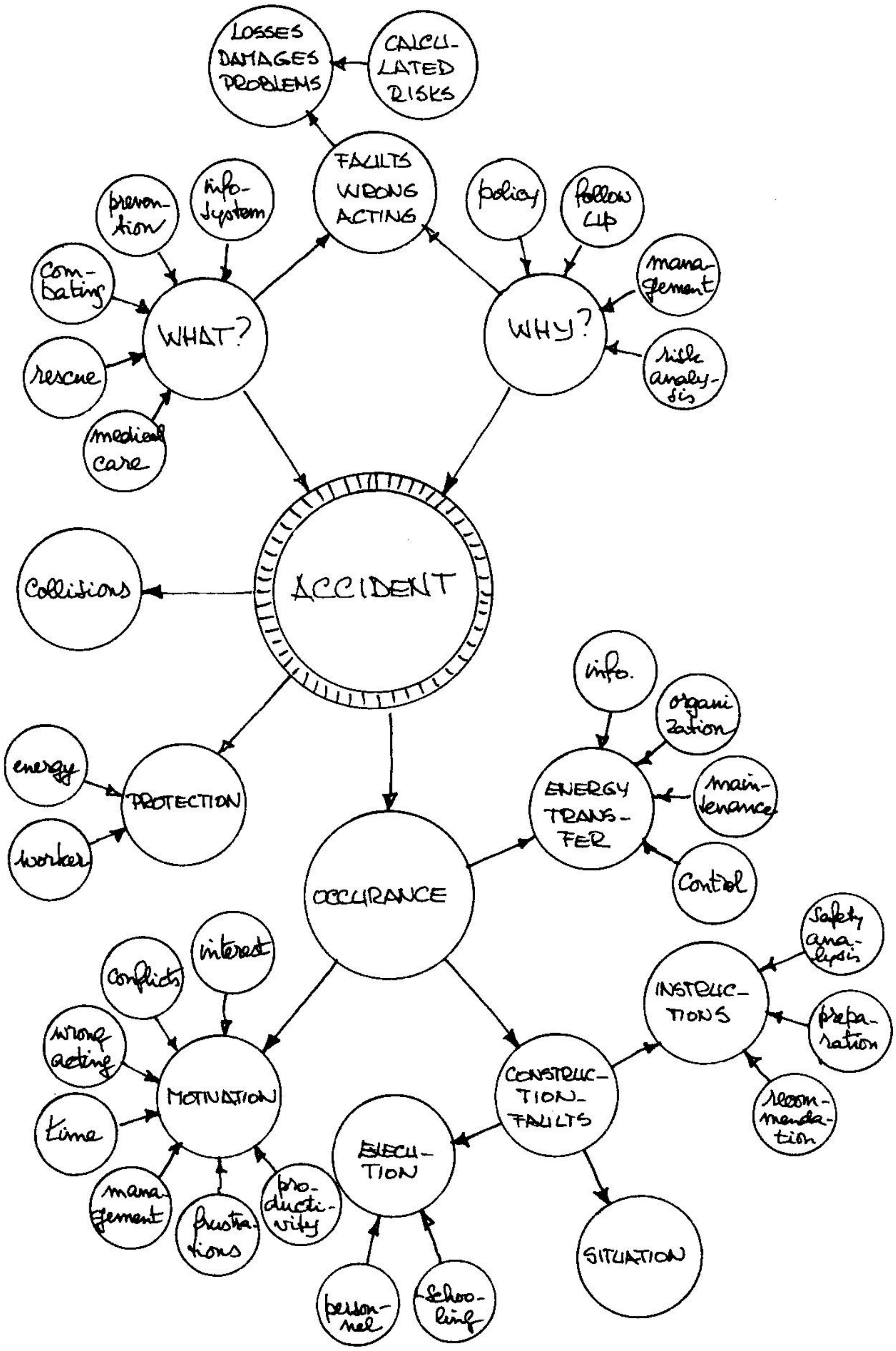


Fig. 12: Principles of MORT

What do we have to do, to prevent more problems? How works our info-system, what kind of prevention do we use; and when something happens: how do we combate the situation, how do we rescue people and what is the medical care that is foreseen?

The occurance of accidents can be thought through before:
- What to do to prevent collisions?
- What kind of protection is necessary, for the workers and for our energy-sources?
- How do we protect the energy-transfer: controle, maintenance, organization, information and instruction
- Could there be something wrong in the field of motivation of men and management: how do we handle production and productivity, frustrations of men, relations with management, time, wrong acting, conflicts and interests?
- Could there be any construction faults? How is the working situation, the excecution of work, the ability of the workers, the instructions about safety, work preparation and recommendations to work?

8.4 Safety-decision-sceme

So we come back to the work on the sites, and we recognise now again the human facotrs and the material factors. We have to analyse both of them, to weigh certain chances.
Is the risk acceptable or not? (fig. 13)
If yes, well let we do the work in the way it is prescribed and foreseen: realise the work.
If we foresee an onacceptable risk, let us not do it in that way: do not realise it.

We think this is clear, and averything is safe!
But when we take the calculated risk, there could happen something that is not wanted by us, or something happens what is not acceptable but that was not foreseen as such! In the working situation now there could happen an accident or there does not happen an accident. Now in both situations we have unsafe working conditions. Only in the case of a real accident we meet the damages and the occurence of injuries.

9. THE SAFETY PLAN

9.1 Why and What

So we come to our safety-program. We want such a safety-plan:
- To reduce human suffering
- To reduce loss of materials
- To promote morale and productivity through safe working
- To reduce insurances rates
- To reduce costs.

Such a program should cover:
- The purpose of the safety-plan
- The scope of it
- The responsibilities
- The establishment of a safety-committee, safety and toolbox-meetings
- The measurements for care and transportation of injures people
- The investigations of accidents and unsafe situations
- The accidents and incidents reports
- The feedback to the organization
- The measures for personal protection
- The instructions to be given
- The organization of safety publications
- The different plans for external assistance.

And we have to do so for the company and for each building site.

9.2 Conditions

So the safety-program and each safety-plan must be supported by the top of the organization, managed by the safety-department or assisted by an external adviser, known by every member of the organization, brought into action on each site and introduced to every newcomer and at the start of each work.

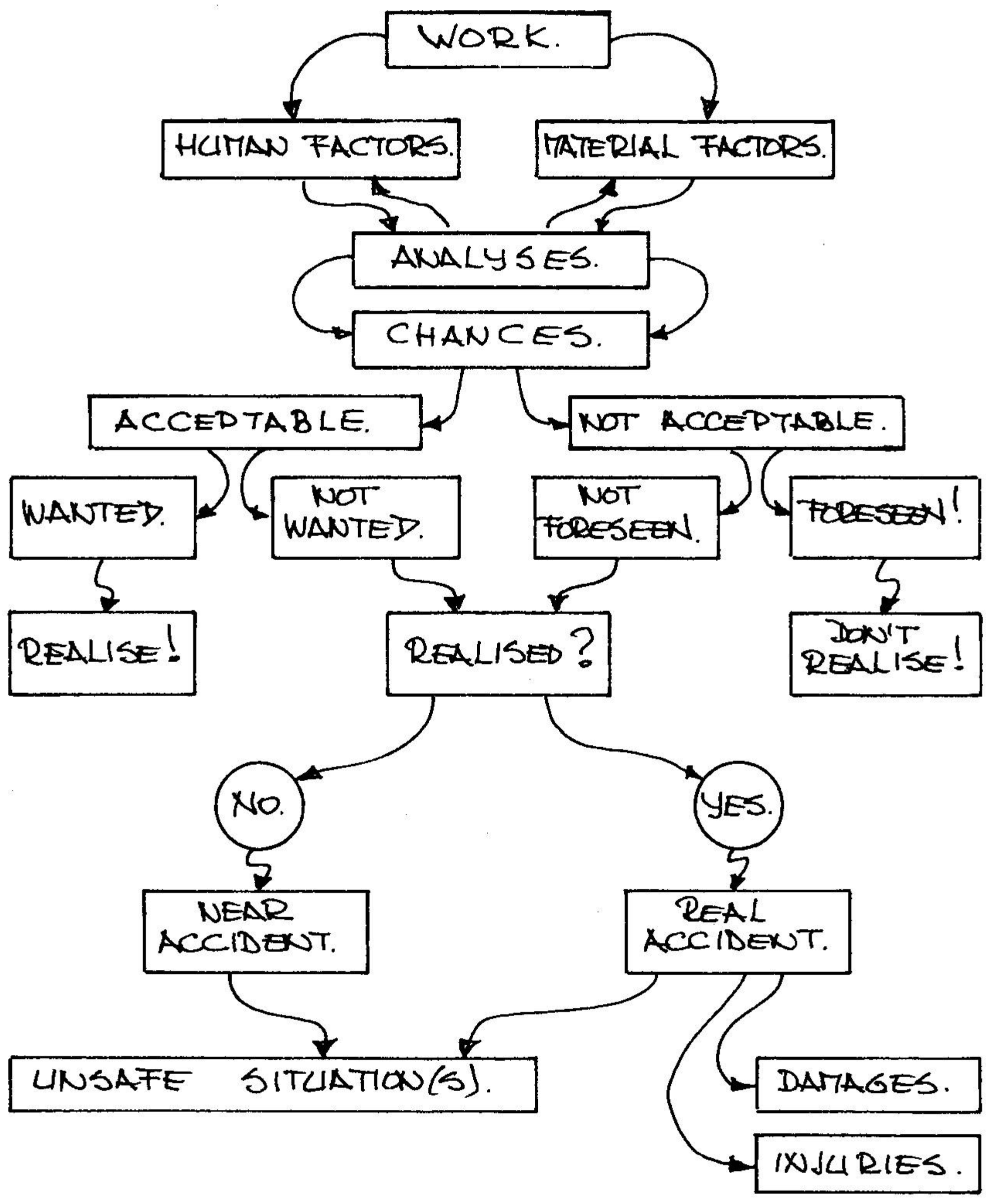


Fig. 13: Safety decision scheme

10. CONCLUSIONS

1. In the Construction Industry we have a big problem in the field of Health and Safety.

2. The number of accidents in the Construction Industry is relatively far more higher than in all other industries.

3. Accidents come form unsafe situations: the unsafe situations occur much more often than we can read from our accident-ratio.

4. Accident-ratio and Health-ratio should be related to each other; an equal definition of these ratio in different countries would give a possibility to compare.

5. Looking to these ratio figures is one thing: far more important is to find a feed back to prevention of accidents, to more safe situations.

6. Safety-Risk analysis give us a tool of management to more safe working conditions.

7. Safety planning and programming is a necessity for each construction company and for each construction site.

8. Safety measures should start at the scourses of possible unsafe actions and circumstances.

9. Safety and Health should be subject for more research and development programs.

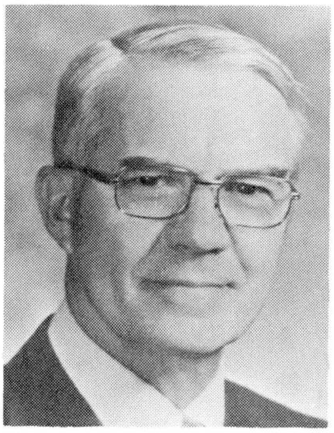
10. Safety is the responsibility for all partners in the construction proces.

Health and Safety in Tall Building Construction

Santé et sécurité dans la construction des maisons hautes

Gesundheit und Sicherheit beim Bau von Hochhäusern

Lynn S. BEEDLE
Director
Fritz Eng. Lab., Lehigh Univ.
Bethlehem, PA, USA



Lynn S. Beedle received his B.S. degree from the University of California (Berkeley) and his M.S. and Ph.D. degrees from Lehigh University. He joined Lehigh in 1947 as Research Engineer. He is also Director of the Council on Tall Buildings and Urban Habitat and Editor-in-Chief of its Monograph on Tall Buildings.

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 trough 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 disponsibles, 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 inbezug 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 frequent 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.

----

*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.

Acknowledgement

This is to acknowledge with thanks the many individuals who supplied literature which was essential resource material for this paper. Many contributed their advice and comment through telephone interviews. Helpful person-to-person interviews were with the following: Cornelius Dennis and staff (New York City Building Department), David Dibner and his staff (General Service Administration), Thomas Gunn (Turner Construction Co.), Ike Martin and his staff (OSHA), Ted R. McKosky (Bethlehem Steel Corporation), John Mullens (U.S. Steel Corporation), and Norman Root (U.S. Bureau of Labor Statistics).

Specific comments on the manuscript were gratefully received from Charles A. Debenidittis (Tishman Speyer Properties), Daniel Head (George A. Fuller Co.), Justin Heinlein and Thomas Gunn (Turner Construction Co.), Jim E. Lapping (Building Construction Trades Department, AFL), Lim Kah Ngam (LKN, Singapore), Ted R. McKosky (Bethlehem Steel Corporation), Joseph H. Newman (Tishman Research Corporation), and Leslie E. Robertson (Skilling, Helle, Christiansen and Robertson).

The preparation of this report has been supported in part by the U.S. National Science Foundation (Grant No. CEE 8105306).

BIBLIOGRAPHY ON CONSTRUCTION SAFETY

American Bridge, Division of United States Steel
AMERICAN BRIDGE SAFETY MANUAL
National Safety Council, .

American Bridge, Division of United States Steel
SAFETY RULES AND REQUIREMENTS FOR SCAFFOLDS

American Bridge, Division of United States Steel
SAFETY RULES FOR WELDING AND BURNING

Arndt, A. P., Glidder, B. and Rees, D. B. 1982
STRUCTURAL SAFETY DURING ERECTION OPERATIONS -- A CONTRACTOR'S VIEW.
(Presented at ASCE Convention), U.S. Steel Corporation.

Bethlehem Steel Corporation 1974
SAFETY CODE
Bethlehem, Pa., 1974.

California Department of Industrial Relations 1977
WORK INJURIES AND ILLNESSES IN CALIFORNIA-QUARTERLY
Division of Labor Statistics and Research, San Francisco, Calif., 1977.

California Department of Industrial Relations 1981
OCCUPATIONAL INJURIES AND ILLNESSES SURVEY CALIFORNIA, 1979
Division of Labor Statistics and Research, San Francisco, Calif., 1981.

California Department of Industrial Relations 1982
1979 CALIFORNIA WORK INJURIES AND ILLNESSES
Division of Labor Statistics and Research, San Francisco, Calif., 1982.

Council on Tall Buildings, Group SC 1980
TALL BUILDING SYSTEMS AND CONCEPTS.ASCE, New York.

Council on Tall Buildings, Group PC 1981
PLANNING AND ENVIRONMENTAL CRITERIA FOR TALL BUILDINGS.ASCE, New York.

Feld, J. 1968
CONSTRUCTION FAILURES.John Wiley & Sons, Inc., New York, New York.

Hinze, J. 1976
THE EFFECT OF MIDDLE MANAGEMENT ON SAFETY IN CONSTRUCTION. Technical Report 209, The Construction Institute, Stanford University.

IIT Research Institute 1973
DESIGNING TO SURVIVE DISASTER. In Conference on Designing to Survive Disaster. IIT Research Institute, Chicago, Il.

Institute of Civil Engineers 1980
SAFE CONSTRUCTION FOR THE FUTURE.The Institution of Civil Engineers, London.

Institute of Civil Engineers 1969
SAFETY ON CONSTRUCTION SITES. In Proceedings of the Conference held at the Institution of Civil Engineers. Institution of Civil Engineers, London.

Levitt, R. E. 1975
THE EFFECT OF TOP MANAGEMENT ON SAFETY IN CONSTRUCTION. Technical Report 196, The Construction Institute, Stanford University.

Levitt, R. E., Parker, H. W. and Samelson, N. M. 1981
IMPROVING CONSTRUCTION SAFETY PERFORMANCE: THE USER'S ROLE. Technical Report 260, The Construction Institute, Stanford University.

Leyendecker, F. V. and Fattal, S. G. 1977
INVESTIGATION OF THE SKYLINE PLAZA COLLAPSE IN FAIRFAX COUNTY, VIRGINIA. Report BSS 94, National Bureau of Standards.

Mainstone, R. J. 1974
THE HAZARDS OF EXPLOSION, IMPACT AND OTHER RANDOM LOADINGS ON TALL BUILDINGS. In ISE/IABSE Conference on Tall Buildings and People. Oxford University, Building Research Establishment Current Paper CP64/74,

McKaig, T. H. 1962
BUILDING FAILURES.McGraw-Hill, New York.

National Erectors Association 1975
CONNECTOR ACCIDENT FREQUENCY SURVEY.

National Safety Council 1981
ACCIDENT FACTS, 1981 FINAL CONDENSED EDITION.

New York City Board of Education, Division of School Buildings 1980
ASBESTOS ABATEMENT/CONTROL GUIDANCE MANUAL
New York, New York, 1980.

New York Society of Architects 1979-80
BUILDING CODE OF THE CITY OF NEW YORK
New York, New York, 1979-80.

Nikai, Sei 1982
SAFETY ASSURANCE CONCEPTS FOR THE CONSTRUCTION OF HIGHRISE BUILDINGS IN JAPAN. In Proceedings Asian Workshop on Health and Safety in Construction, pages . Japanese Group of IABSE, Tokyo.

Pals, J. H., Kane, J. D., and Marcello, J. S. 1982
PILOT PROGRAM TO EVALUATE THE EFFECTIVENESS OF OSHA CONSTRUCTION STANDARDS AT THE POINT OF ERECTION. Final Report NIOSH #210-81-3008, Western Institute for Research and Education, Inc.

Samelson, N. M. 1977
THE EFFECT OF FOREMEN ON SAFETY IN CONSTRUCTION. Technical Report 219, The Construction Institute, Stanford University.

The University of Michigan 1977
OCCUPATIONAL FALLS. Final Report UM-HSRI-77-51, Highway Safety Research Institute, University of Michigan.

U.S. Department of Labor 1979
OSHA SAFETY AND HEALTH STANDARDS: CONSTRUCTION INDUSTRY
OSHA, Washington, D.C., 1979.

U.S. Bureau of Reclamation 1968
CONSTRUCTION SAFETY STANDARDS
1st edition, U.S. Department of the Interior, 1968.

U. S. Department of Labor 1978
RECORDKEEPING REQUIREMENTS UNDER THE OCCUPATIONAL SAFETY AND HEALTH ACT OF 1970. Technical Report, Occupational Safety and Health Administration.

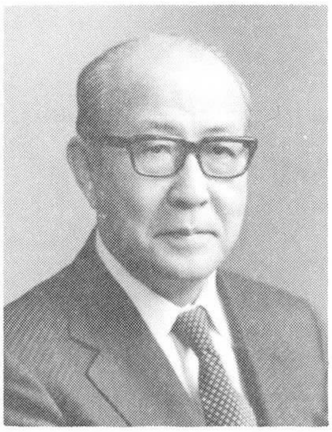
U. S. Department of Labor 1982
OCCUPATIONAL INJURIES AND ILLNESSES IN THE UNITED STATES BY INDUSTRY, 1980. Bulletin 2130, Bureau of Labor Statistics.

Safety Assurance Concepts for the Construction of Highrise Buildings

Concepts de sécurité pour la construction de maisons hautes

Sicherheitskonzepte für den Bau von Hochhäusern

Sei NIKAI
Exec. Vice President
Kajima Corporation
Tokyo, Japan



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.

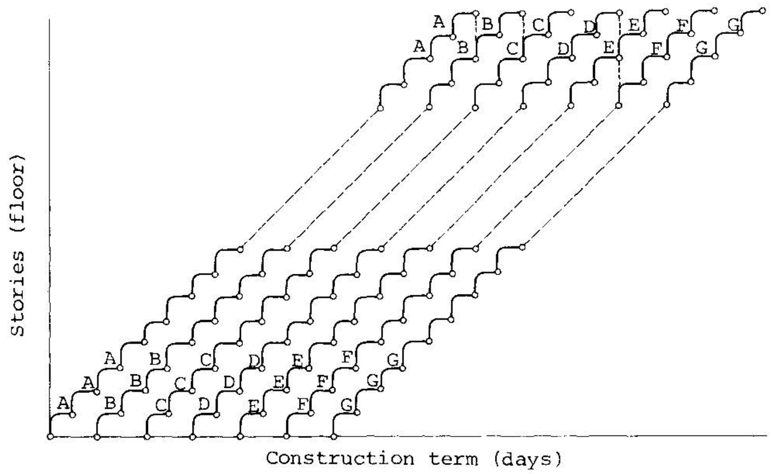


Fig. 1 Sequential Repetition Method

Legends

A: Steel erection works

B: Floorslab works

C: Fireproofing works

D: Curtain wall works

E:, F:, G: Ceiling and interior finish works

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.

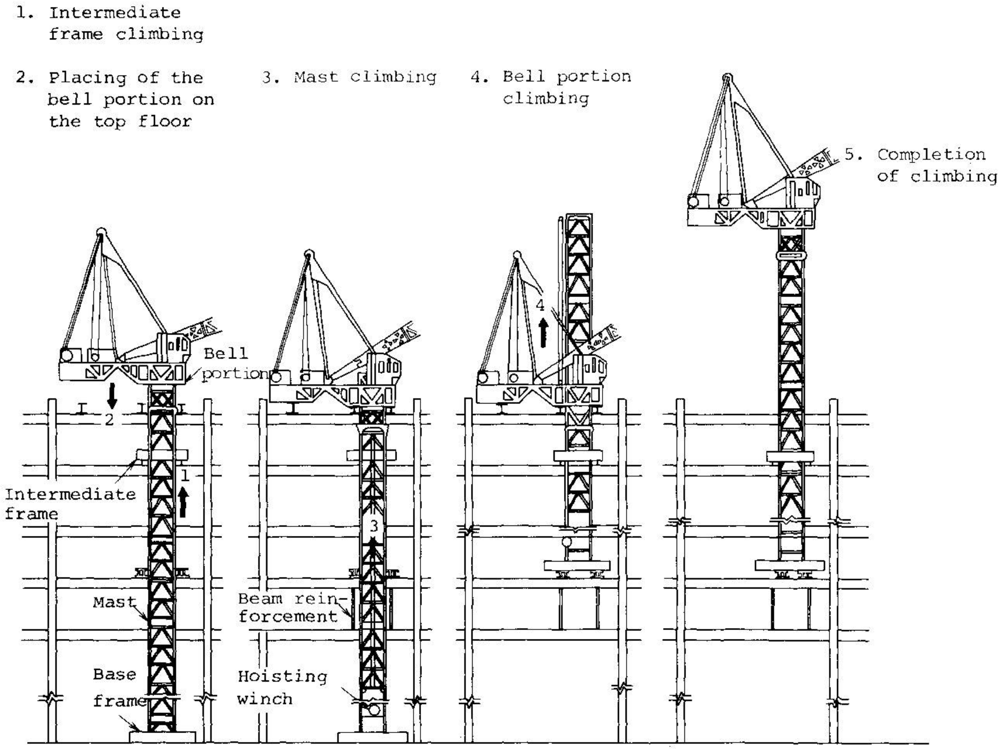
The safety of the crane is controlled by the Labor Safety and Sanitation Law, Regulations Related To Cranes and Other Equipment, and other regulations. Cranes are also well-equipped with a variety of safety devices.

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.

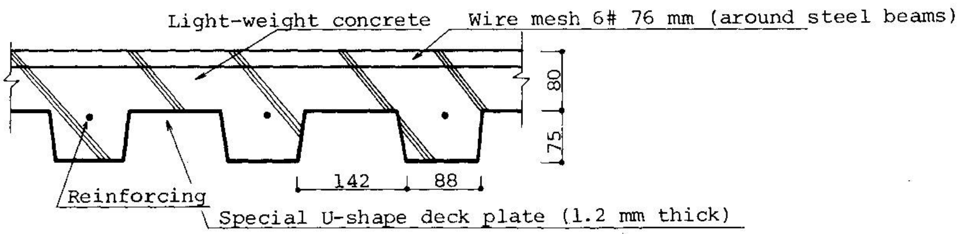


Fig. 3 Special Light-weight Concrete Slab Cross Section

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.

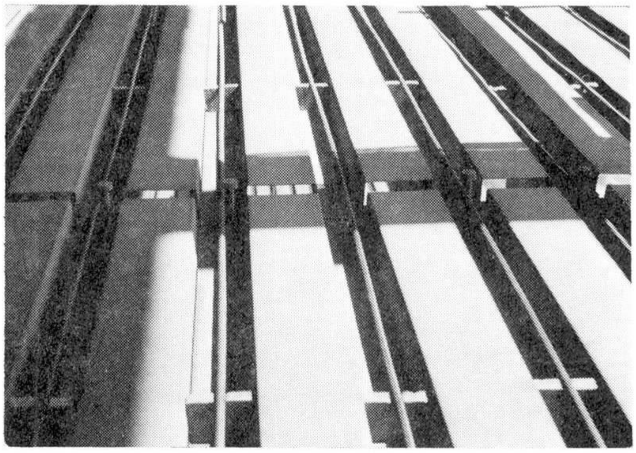


Fig. 4 Floor bar arrangement

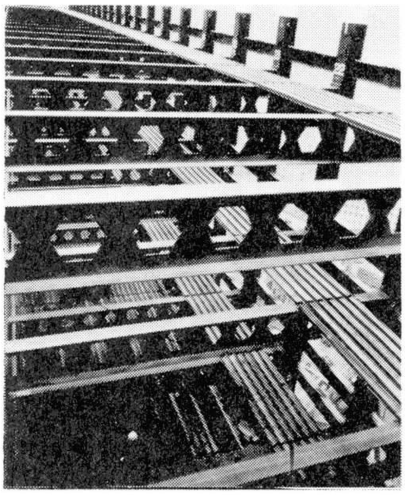


Fig. 5 Temporary passage ways covered with deck plate, for safety

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.

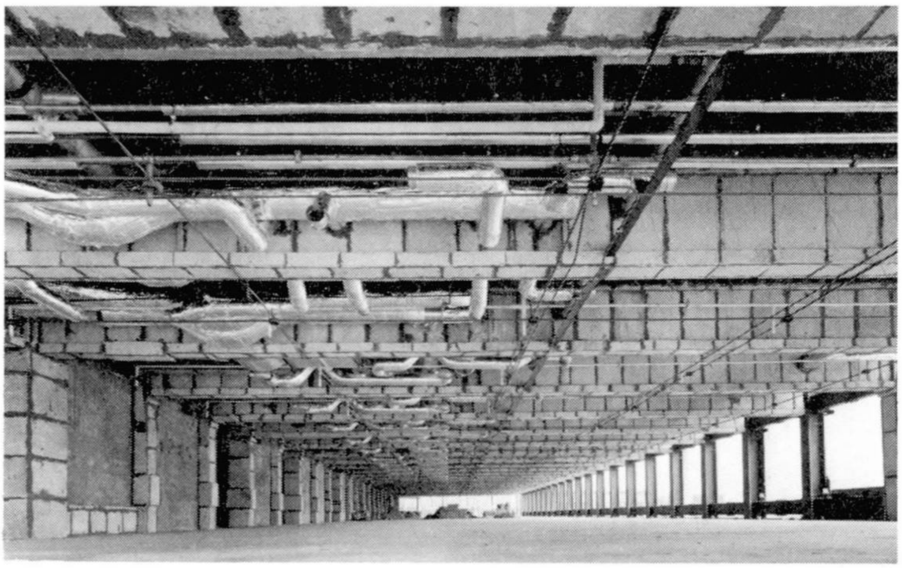
Steel-framed buildings need fireproofing to prevent deterioration of their columns and girders, and the resultant damage to the structures, in times of fires.

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.

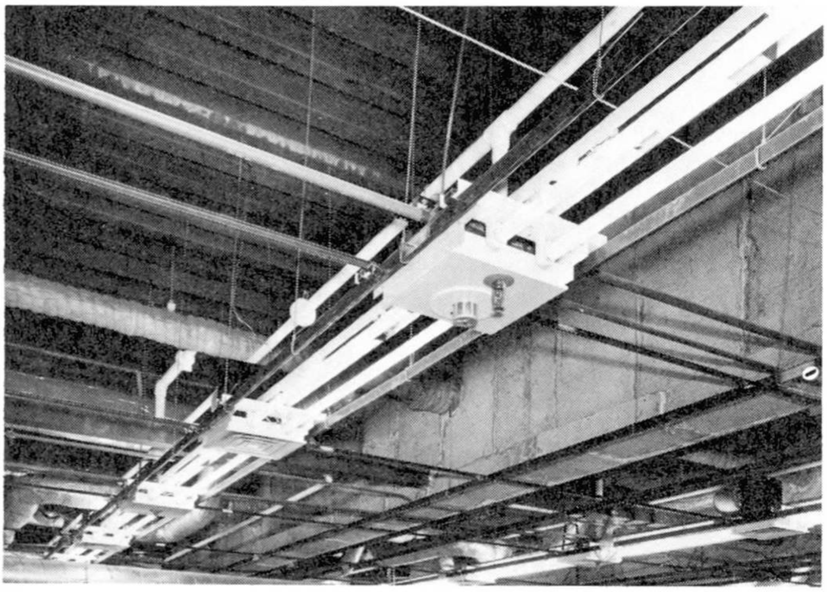


Fig. 8 Preinstallation process

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.

REFERENCES

1. NIKAI, S., Highrise Buildings, Vol. 4 Construction, Kajima Publishing Co., Ltd., 1972

2. NIKAI, S.,Highrise Buildings, Construction - second series, Kajima Publishing Co., Ltd., 1977

3. NIKAI, S., "Thesis: A Study on the Rationalization of Work Schedule and the Development of Technology for the Construction of Highrise Buildings", 1967

Leere Seite
Blank page
Page vide

Safety Measures for Construction of the Honshu-Shikoku Bridges

Mesures de sécurité dans la construction des ponts de Honshu-Shikoku

Die Sicherheitsmassnahmen bei der Ausführung von Honshu-Shikoku-Brücken

Hirosuke SHIMOKAWA
Counsellor for Engineering
Honshu-Shikoku Bridge Authority
Tokyo, Japan

Hirosuke Shimokawa, born 1926, got his civil engineering degree at the University of Kyushu, Fukuoka in Japan. He realised many projects of highways and bridges in the Ministry of Construction for 30 years and he left from the director of Kyushu Construction Bureau in 1979. Hirosuke Shimokawa, now in the Authority, is responsible for the design and construction of the structures.

SUMMARY
This report describes the safety measures taken for the construction work of the Honshu-Shikoku Bridges which is one of the largest projects in Japan. Emphasis is put on the construction of the Ohnaruto suspension bridge.

RESUME
Ce rapport présente les mesures de sécurité dans la construction des ponts Honshu-Shikoku qui est un des plus grands projects actuels au Japon. La construction du pont suspendu à Ohnaruto est considérée en particulier.

ZUSAMMENFASSUNG
Die Sicherheitsmassnahmen bei der Ausführung des Honshu-Shikoku-Brücken-Projektes, das zur Zeit das grösste Projekt in Japan ist, werden hier kurz beschrieben. Im Besonderen wird die Ausführung der Ohnaruto-Hängebrücke behandelt.

PREFACE

This report describes in outline the safety measures taken for the construction work on the Honshu-Shikoku Bridge. This report will describe the specific safety measures taken in the construction of large span bridges at straits, which is this project's most important characteristic.

1. OUTLINE OF CONSTRUCTION WORK

Constructing of the Honshu-Shikoku Bridges aims to provide efficient and smooth transportation between Honshu and Shikoku islands. The bridges will become part of the national trunk highway and railroad networks. In addition, they will relieve the congested marine traffic in the Seto Inland Sea and so reduce the number of marine accidents.

An overall view of the Honshu-Shikoku Bridges is shown in Fig. 1 and Table 1. The bridges completed and under construction are shown in Table 2.

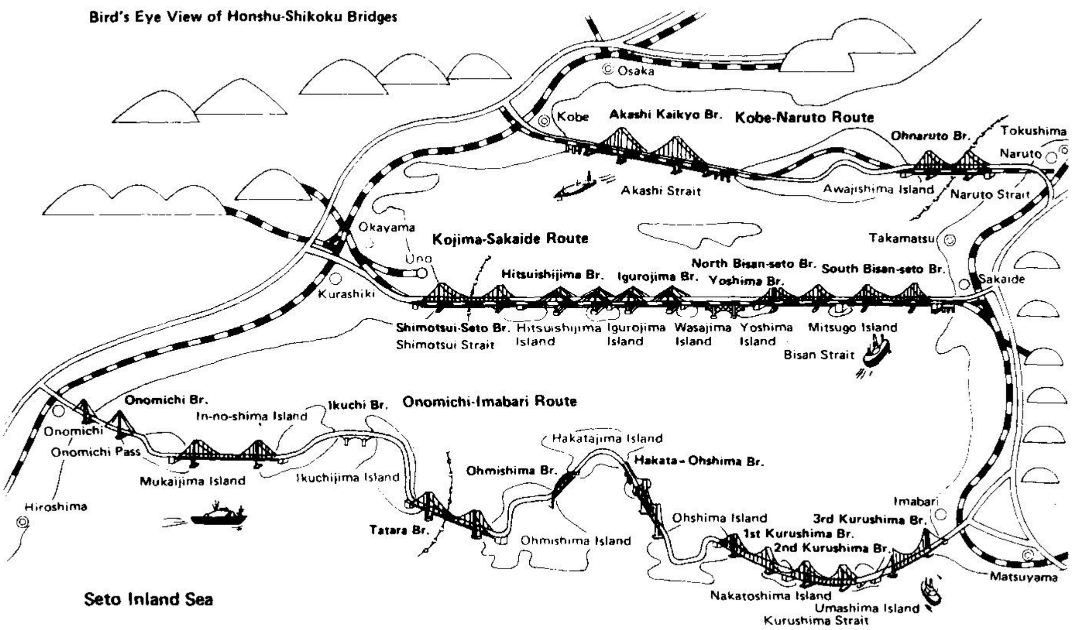


Fig. 1 Overall View

Item	Category	Particulars	Kobe-Naruto Route	Kojima-Sakaide Route	Onomichi-Imabari Route
Length (km)	Highway		81.1	37.8	60.1
	Railway		89.8	49.2	-
Structural standards	Highway	Classification	Type 1, 2nd class	Type 1, 2nd class	Type 1, 3rd class
		Design speed (km/h)	100	100	80
		Number of lanes	6 (partially 4)	4	4
	Railway	Classification	Shinkansen	Ordinary line and Shinkansen	-
		Number of tracks	2	2+2	-
Construction cost (billion yen) (FY1977) 2,400			1,150	840	410

Table 1 Length, Structural Standards and Construction Cost

Name	Type	Span length (m)
Ohnaruto Bridge	Suspension	93 + 330 + 876 + 330
Shimotsui-seto Bridge	Suspension	230 + 940 + 230
Hitsuishijima Bridge	Cable-stayed	185 + 420 + 185
Igurojima Bridge	"	185 + 420 + 185
Yoshima Bridge	Truss	154 + 204 + 154
North Bisan-seto Bridge	Suspension	274 + 990 + 274
South Bisan-seto Bridge	"	274 + 1,100 + 274
In-no-shima Bridge	Suspension	250 + 770 + 250
Ohmishima Bridge (completed)	Arch	297
Hakata-Ohshima Bridge	Girder	90 + 145 + 90
	Suspension	140 + 560 + 140

Table 2 Bridges Completed and Under Construction

The construction works are performed in areas of the Seto Inland Sea National Park having sea, many islands and complicated shorelines and some of the most beautiful natural scenery in Japan. In addition, strong winds frequently blow in this area and the size of the bridges is very large, so the highest precautions shall be taken for the safety of the construction workers and the conservation of the natural environment. Various kinds of industries have been developed in the Seto Inland Sea area to make it an important industrial zone in the southern part of Japan. The Seto Inland Sea has served as a main waterway connecting Honshu, Shikoku and Kyushu islands and is congested with many ships. On the other hand, the bridges must be constructed under severe natural conditions of submarine topography, tidal currents and fog, so that various measures must be taken to secure navigational safety.

2. SAFETY FUNDAMENTALS DURING CONSTRUCTION

The prevention of accidents is the most important problem in the construction of the Honshu-Shikoku Bridges, and various kinds of safety measures have been taken as well as ordinary precautions.

General items related to the safety of construction work will be described in this section.

2.1 Organization for executing the work

The main portions of construction work such as the superstructure and substructure are preformed by construction companies in contract with the Authority in the form of joint ventures (JV) of two or three special companies, chosen from this country's top firms. All of the important items related to safety are described in the contract documents and are under the direct guidance and supervision of the Authority and the safety officials of the Ministry of Labor.

2.2 Laws

Construction work is carried out in accordance with laws, government ordinances and ministry rules. The most basic laws are the Labor Standards Law and the Labor Safety and Health Law but the work is also carried out under various laws for the safety of navigation, ports and harbours, prevention of ocean polution, natural parks, fire prevention, and so on.

2.3 Engineering standards

Design standards accepted widely in Japan for ordinary structures cannot be perfectly applied to the Honshu-Shikoku Bridge Project, so many engineering standards must be established by the Authority itself. These standards contain very sophisticated techniques as well as newly developed ones, which were thoroughly investigated and prepared by excellent researchers and engineers in this country. Principal examples are listed in Table 3.

General specifications for construction work
Guidelines for the safety of common construction works
Guidelines for the safety of marine construction works
Design standard for multi-cell type buffer
Design standard for composite type buffer

Table 3 Examples of Standards for Safety

2.4 Contracts

The specifications require the contractors to execute the work while maintaining the safety and to submit a plan for the actual work before its commencement. Important portions including the safety measurements shall be approved by the Authority. The contractors are obligated to execute the work in accordance with the specifications and the plans approved by the Authority, and the Authority is to supervise and inspect the work.

Principal safety items imposed on the contractors are as follows:

1) Submission of the plan for the execution of work and its approval by the Authority
2) Obedience to the Guideline for the Safety of Common Construction Works
3) Obedience to the Guideline for the Safety of Marine Construction Works
4) Determination of meteorological conditions and sea phenomena during which work is not to be performed
5) Assignment of traffic controllers on land
6) Assignment of safety supervisors
7) Participation and cooperation with the navigation control room
8) Arrangement of observation ships, which give informations, warnings, guidances and so on to the common ships if necessary.

2.5 Safety control system

2.5.1 Organization for field safety control

The contractor shall establish a safety control organization for each construction area. An example of this is shown in Fig. 2. The safety controllers and health controllers must be the full-time workers.

Safety organization for the district controlled by o o o Construction Office
(an example of relation between the Authority and JV)

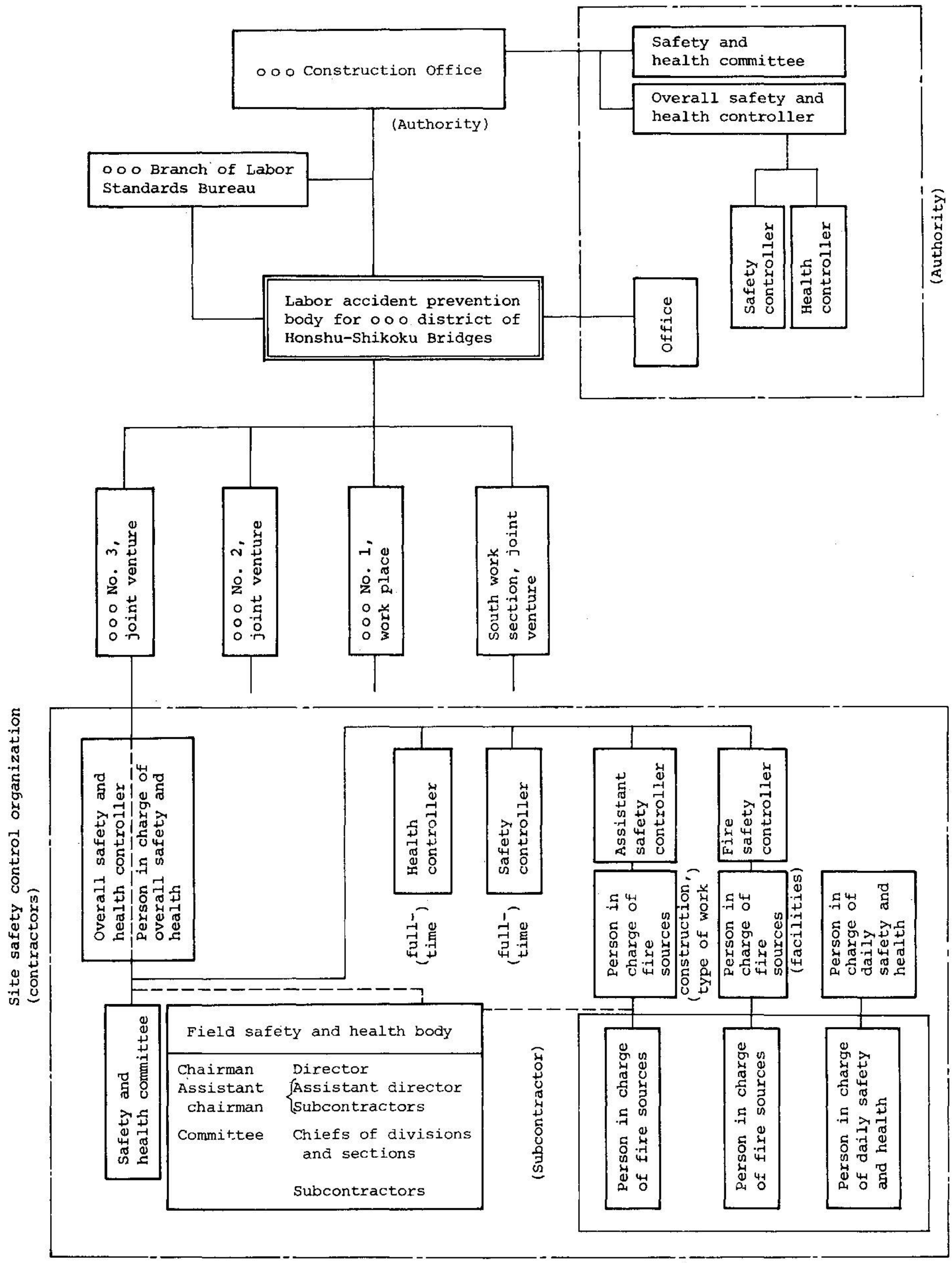


Fig. 2 An Example of safety control for the construction of the Honshu-Shikoku Bridges

2.5.2 District labor accident prevention body

This is a united body of the safety control organizations provided for each district where several works are being carried out. Ordinarily, this body is provided for each construction office of the Authority, and its members consist of staff of the Authority, Labor Standards Bureau and contractors of the works under the Authority's office. This body provides coordination between several works since the work sites overlap and construction roads and facilities are being commonly used. Also the body gives convenience of guidance and coordination by the Authority and the Labor Standards Bureau.

2.5.3 Liaison committee for the promotion of construction safety for the Honshu-Shikoku bridges

This committee consists of the staff of the Ministry of Labor and the Authority, and meetings of regional staffs of both organizations are periodically held to promote safety on the Honshu-Shikoku Bridge Project, designated as a special large scale project by the Ministry of Labor.

2.5.4 Navigation control room

This control room is provided for each sea work zone, in order to collect and transmit information related to work, weather, marine conditions and traffic, and is expected to promote the safe sailing of common ships around the site and the smooth execution of construction work by centrally controlling of the sailing of construction vessels and observation ships.

2.5.5 Committee for review of construction safety

This committee consists of staff of the Authority and collects information related to work safety on the project. If any accident occurs, the committee investigates the situation, determines the cause of the accident and reviews the necessary measures to be taken. Every month the committee receives safety inspection and accident reports from each site. The situation of occurrence of the accidents of the project is shown in Table 4.

As of end of June 1982

	Total number of hours of labor (man-hour)	Numbers of the dead and the injured (persons)				Number of labor days lost (days)	Frequency factor	Intensity factor
		Deaths	Absence of more than 8 days	Absence of less than 7 days	Total			
No. 1 Construction Bureau	9,174,046	2	25	3	30	16,812	3.27	1.83
No. 2 Construction Bureau	7,441,116	3	4	2	9	22,680	1.21	3.05
No. 3 Construction Bureau	5,739,505	1	22	5	28	9,629	4.88	1.68
The Authority as a whole	22,354,667	6	51	10	67	49,121	3.00	2.20

References		Frequency factor	Intensity factor
	National average in 1981 for road construction	3.84	1.38
	National average in 1981 for bridge construction	3.24	0.65

Frequency factor: Number of deaths and the injured due to labor accidents per 1 million labor hours $= \dfrac{\text{Number of deaths and injured}}{\text{Total labor hours}} \times 1{,}000{,}000$

Intensity factor: Number of labor days lost per 1,000 labor hours $= \dfrac{\text{Number of labor days lost}}{\text{Total labor hours}} \times 1{,}000$

Note: Values shown in the above table are the totals for the works (including works under construction) executed by the Authority.

Table 4 Labor accidents on the Honshu-Shikoku Bridge Project

3. NAVIGATIONAL SAFETY

The straits around the construction are important navigational areas for east-west and south-north bound sea traffic in the Seto Inland Sea and have been good fishing grounds since long ago. For these reasons, the bridges will greatly affect safety of the navigation not only during their construction but also after completion and thus, it is extremely important to carry out the bridge project while securing the safety of sailing ships and fishing boats in the area.

3.1 Survey and study by the Authority

In order to establish actual safety measures for navigation, the Authority has been studying the following items in collaboration with researchers and the administrative bodies concerned: ⓐ actual situation of the sailing of ships and required span lengths and clearance of the bridges based on future forecasts, ⓑ navigational aids such as center lights in the waterway, lighting for bridge piers, fog signals and so forth, ⓒ Collision prevention facilities, and ⓓ arrangement of safety facilities during work, arrangement of observation ships, and thorough information exchange.

False images occasionally appear on ships radar due to large bridges and these create a navigational safety problem for ships. Thus, the Authority is now carrying out studies on the following items: ⓐ development of a forecast method for the appearance of false radar images, ⓑ forecast of appearance of false radar images for each bridge, ⓒ degree of interference to navigation, and ⓓ development of radio wave-absorbing materials.

3.2 Navigational safety measures

In order to fully secure safety of the navigation for ships around the site during construction, a navigational control room has been established to centrally control information and maintain close coordination with authorities arrange safety system. They function as listed below in response to the traffic environment and natural conditions in the sea areas where construction work is being carried out: ⓐ established the working sea surface and indicating it by buoy lights, ⓑ arrangement of patrol ships, ⓒ assignment of members for safety patrol, ⓓ arrangement of communication network, and ⓔ transmission of construction information.

As for the safety measures for navigation after completion, the influence of the bridges upon ship traffic was studied, and facilities required for the safe navigation of ships were examined for each bridge in response to traffic, environment and natural conditions in the sea areas. By checking the increases in future traffic, the Authority will take positive and effective navigational safety measures.

4. SUBSTRUCTURES

In substructure construction works for the Honshu-Shikoku Bridges, safety measures have been considered from the planning stage. As typical examples, some actual measures concerning multi-column foundations and the laying-down caisson foundations were newly developed in the Honshu-Shikoku Bridge Project. These will be described.

A multi-column foundation consists of several columns embedded into the sea bed and a rigid footing at the top connecting them, as shown in Fig. 3. Natural conditions at the pier sites of Ohnaruto Bridge, where this foundation is used, are very severe because of the maximum depth of 6.2 m, the maximum tidal velocity of 8 knott, and direct strong storms from the Pacific Ocean.

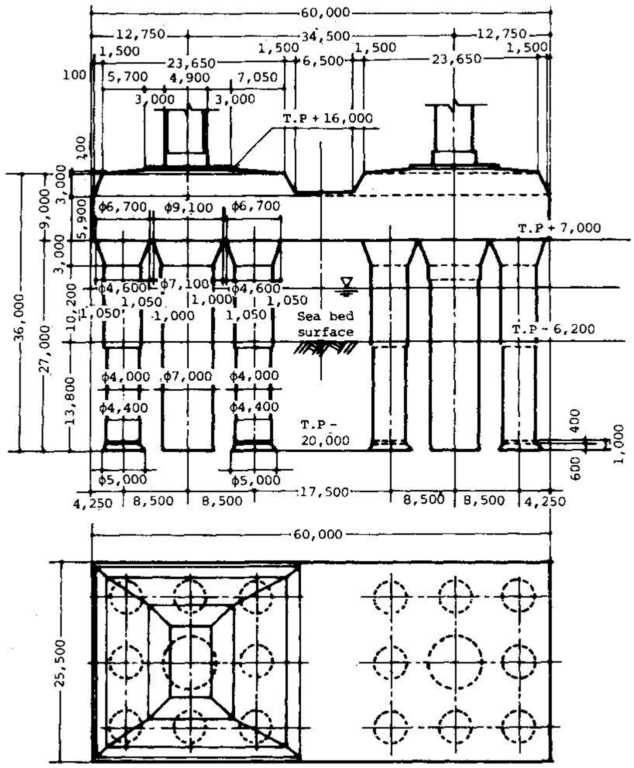


Fig. 3 Multi-column foundation

The sea bottom with alternate layers of sandy rock and shale is so complicated topography that ships have difficulty passing through there. On the other hand, the surrounding areas are famous places in the Seto Inland Sea where National Parks and fishery prospers. Therefore, environmental pollution is never permitted.

Under such conditions, there is a pneumatic caisson, one of the types of alternative foundation, except a multi-column foundation. Finally a multi-column foundation was selected, because the pneumatic caisson needs an island vuluner-able to storm and manual excavation in compressed air under the sea level. Multi-column foundation work consists of constructing a platform around the foundation and of columns and footings. This platform is composed of steel pipes and settled by a crane vessel, step by step in a big block, for the reasons in order to decrease the works on the sea, in order to avoid the ocean wave and in order to evade a disaster under construction by reduction of operations at site. The platform founded on the sea bed rock directly is planned to withstand violent climate.

A multi-column foundation has the advantage of machine excavation being possible from the sea platform. But, sea pollution due to leakage of drilling mud water must be prevented. In order to perfectly prevent leakage, a water sealing frame was arranged and sealing concrete was cast at the bottom of a casing tube. After drilling muddy water using is purified by a plant on land and was then discharged in the sea.

Because of such perfect preparation, the construction of multi-columns foundations has successfully finished notwithstanding severity of site conditions. It is remarkable that the foundations have been completed without accident in spite of the construction work using various heavy machineries on the platforms.

An outline of a laying-down caisson method is illustrated in Fig. 4. Firstly, the sea bed is excavated and trimmed upto the bearing layer so that a steel caisson fabricated at a shipyard may be placed at the accurate position. After setting a caisson, precast concrete is cast inside. Finally it becomes a rigid foundation.

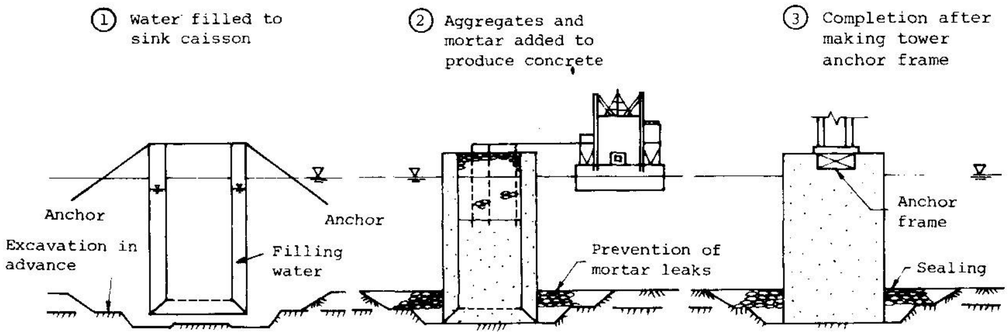


Fig. 4 Method of laying-down caisson

The South and North Bisan-Seto Bridges to which this foundation method is applied, consist of two suspension bridges of 3 spans continuous stiffening girders with a total length of 3,335 m. Six foundations, which are 2 anchorages and 4 piers, of 7 in total are to be constructed in the sea. At these sites, the maximum depth is about 50 m and the maximum tidal velocity is 5 knotts. The sea bed is granite, but the rock is so weathered that it needs the excavation of much rock to reach the bearing layer. More than 1,000 ships pass through the strait every day and fishery is prospering there. For these reasons, several restrictions are imposing on the Authority's demand to occupy some sea area as the construction area.

Under the conditions mentioned above, several types of foundation including pneumatic foundations are possible. However, among them, a laying-down caisson method was selected, because it decreased risky submerged works in such deep places, complicated works on the sea and influence on the navigation and the fishery by reduction of construction period at the site.

Under-water blasting was adopted for rock excavation. Almost all works for the excavation was performed on a self-elevating platform except insertion of explosives and supervising. After blasting, crashed rock is dredged by grabs on vessels. Surface of the rock under the edges of the caisson are trimmed by drilling machines on a self-elevating platform.

For blasting work, some severe guidelines have been established, and the time and the zone of blasting has been thoroughly informed to the public. Also special underwater blasting methods and explosives were newly developed in order to satisfy various situations of the construction work, as shown in table 5. These explosives were water-proof and effectiveness for a long time so that they can endure tidal currents, water pressure and impact. A new method was developed to enable to simulate blasting effects, propagation of vibration, sound, pressure and so on with an electronic computer. Using this method, the construction work was carried out without undesirable influence to fish and shellfish.

Blasting method	Initiating method	Applicable foundation	Characteristics
Detonating fuse initiation	Detonating fuse	3P 4A	a. Where the explosive can be loaded by divers, large-scale blasting can be made relatively easily, safely and surely. b. Good for shallow water and low speed tidal currents.
Supersonic wireless initiation	Wireless (supersonic type)	5P	a. Not affected by tidal currents. b. Detonating elements are to be held on the sea bottom where the sedimentary layer is thick. c. Can be used in the sea far from land.
Electro-magnetic induction initiation	Wireless (electro-magnetic induction)	6P	a. Not affected by thickness of sedimentary layer. b. Loop antenna is to be retained where tidal current is high. c. Installation accuracy of loop antenna and electromotive force are to be fully controlled.
Wired, phased initiation	Wired	7A P: Pier A: Anchorage	a. Phased blasting by timer of blaster is possible. b. Retaining of circuit is difficult where tidal current is high. c. On-land or SEP is required.

Table 5 Underwater blasting method

So far there has been no accident during rock excavation whose maximum volume at one foundation is 600,000 m^3. On the other hand, supporting facilities have been used in cooperation with the Authority and Japan Marine Science and Technology Center in order to improve safety of the divers and health management.

The steel caissons have been set very exactly by operations of a special control system and a large-capacity crane vessel. After setting a caisson, to fulfil precast concrete inside, a special mortar plant vessel is used. Owning to the utilization of this vessel, a big reduction of construction period and minimization of the sailing of the working ships crossing the waterway have become possible.

The Authority has made many safety measures not only for foundation works but also for navigation and fishing boats.

5. SUPERSTRUCTURE WORK

An outline of work with an emphasis upon the safety measures actually taken will be described here for the main towers, the cables, and the stiffening girder of Ohnaruto Bridge. A schematic drawing of Ohnaruto Bridge is shown in Fig. 5.

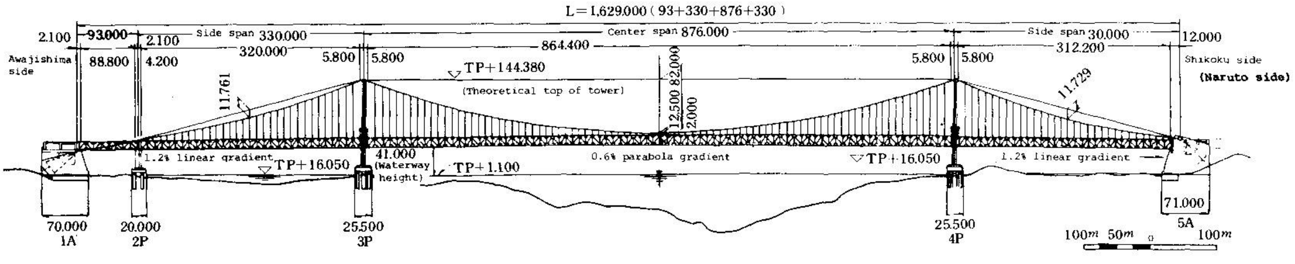


Fig. 5 General view of Ohnaruto Bridge

5.1 Main Tower Work

As shown in Fig. 6, the structure of the main tower is divided into 13 parts in its height, and each part is separated vertically into three blocks excepting the top portion of tower and the fifth part for installing horizontal member. Each tower is divided into 84 blocks including blocks for diagonal and horizontal members.

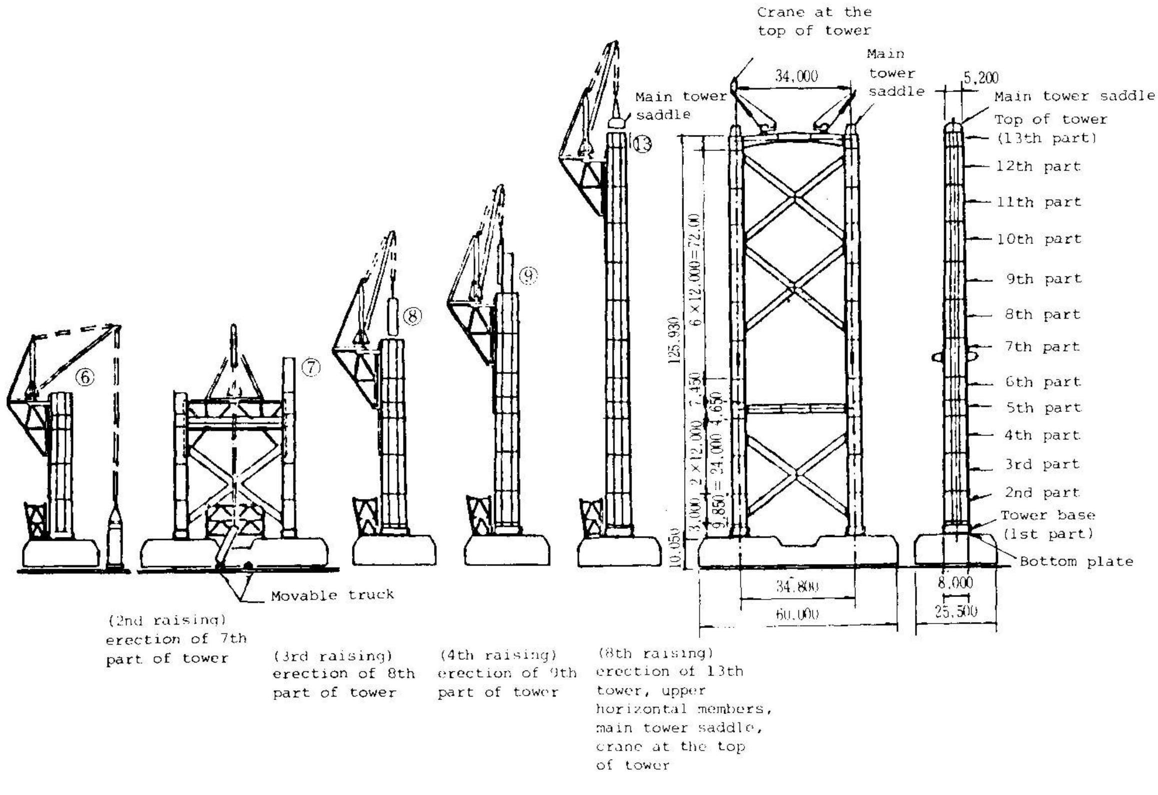


Fig. 6 Steps of erection of main tower

During the erection procedure, blocks which were transported by a pontoon from the fabricating factory in accordance with the work schedule are unloaded by a tripod derrick crane, moved laterally by a truck and then lifted and erected by a creeper crane.

The first to fourth parts of the tower are erected by the creeper crane standing itself, but the parts after the fifth part are erected by the creeper crane which is sequentially installed to the tower already erected.

Blocks are connected with bolts and scaffolds are installed in advance to the joints of the previously erected blocks. These scaffolds are used for work such as the driving of drift pins, tightening of final bolts and painting. Since assembly of these tower scaffolds is the most dangerous work on the tower, special safety measures are being taken as shown in Fig. 7. That is, for reducing the work at high places to a minimum, all portions other than handrails shown by the dotted line in the figure are assembled on the ground and installed in advance to the blocks. Upon completion of erection of all 3 blocks of A, B and C, scaffold boards are assembled for the remaining portion and handrails are installed to provide the scaffold more safety. Other safety measures taken include the spreading of the scaffold boards around the tower shafts, elimination of gaps between the scaffold boards and the structure, installation of protection nets to all portions of the floor and handrails in order to prevent small tools and materials from dropping, and attaching ropes to the tools in order to avoid accidents caused by their droppage.

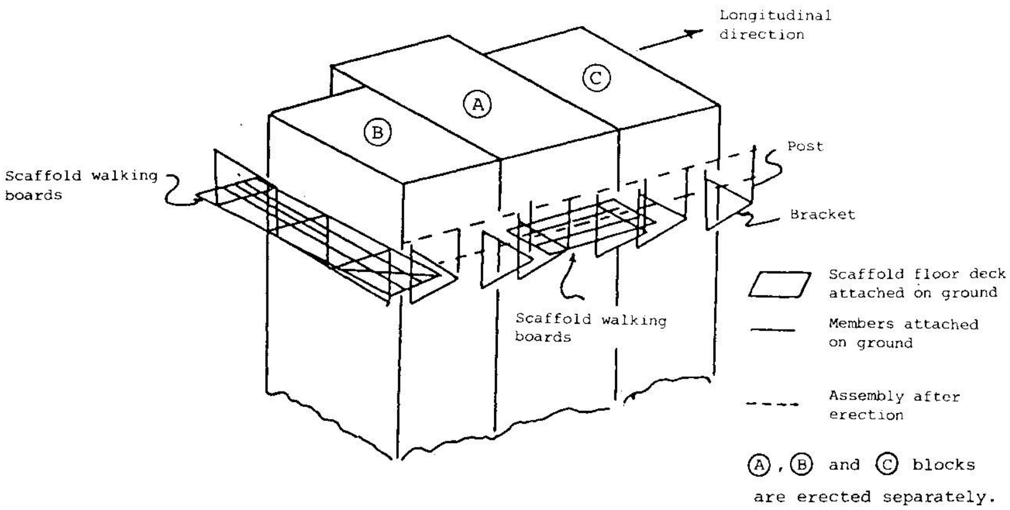


Fig. 7 View of on-ground assembly

Also, since the creeper crane is the most important machine for erecting the tower, it is carefully inspected and maintained. Thus, daily and monthly inspection tables for its mechanical and electrical systems are provided in detail.

5,2 Cable work

The size of the main cable of Ohnaruto Bridge is 840 mm in diameter and 1,722 m in length, and the cable consists of about 20,000 galvanized steel wires, of 5.37 mm diameter. One main cable consists of 154 strands, and each strand comprises 127 wires bound in parallel at the factory and has a regular hexagonal section.

The strands are pulled out one by one along the scaffold in the air called the "catwalk" from the anchorage at the Naruto side to the anchorage at the Awaji-shima side and they are anchored to the cable anchor frames.

The kinds of work requiring special safety measures include the stretching of the pilot rope and the erection of the catwalk.

The spinning of pilot ropes was to be performed in the sea area where there are many reefs and tidal current is very fast. In order to provide safety to the work at such place, a free hang method was adopted, which aerially stretches a rope from the tower by a boat without floats. However, since the spanning of the pilot ropes would fully block the strait, many efforts were made to ensure safety of third parties such as fishing boats and marine workers. The spanning work had been publicly announced and observation ships were on duty on the day of the spanning. Public announcements were made through television, radio, newspapers as well as by the distribution of posters to those concerned. Posters written in English were also mailed to various organizations in the world about two months prior to the date of spanning work.

Because the catwalk must be useful for a long period of time not only for the erection of strands but also for adjustment strand sag at night, squeeze work, erection of cable bands, and erection of hanger ropes, it must be strong and provide high safety. The structure has lateral beams, welded wire mesh, drop prevention nets,walking steps and handrails all which are installed to the top of the catwalk ropes. (Fig. 8)

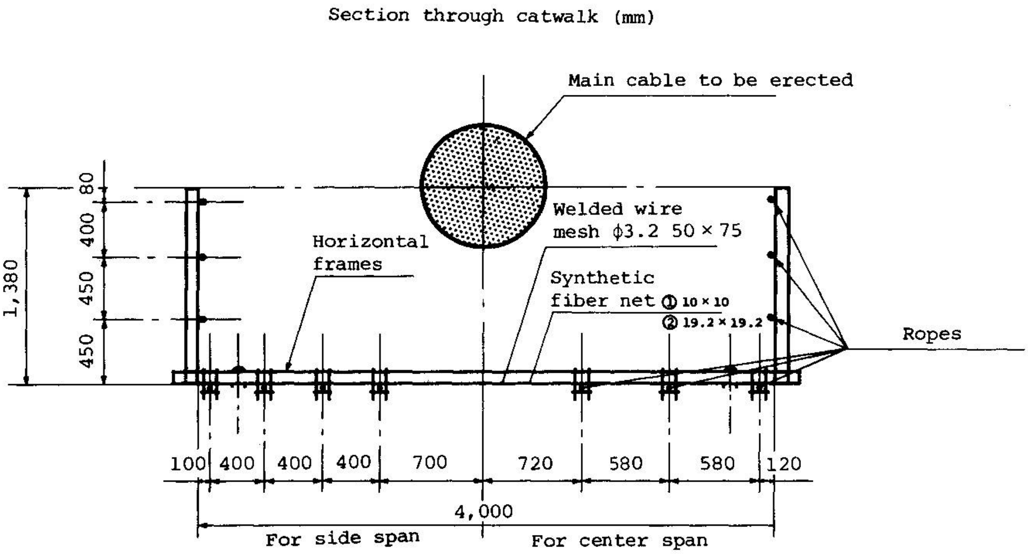


Fig. 8 Structure of catwalk

In erecting the floor assembly of welded wire mesh and nets, it was necessary to reduce work on the sea surface and high places to a minimum, so the wire mesh was rolled into a coil in advance, which enabled us to do the work easier.

Works conventionally performed in a narrow space at the top of the tower was transferred to the ground in order to simplify the work, and works carried out at the top of the tower was only to install the lateral beams and the handrails according to uncoiling of the wire mesh.

5.3 Stiffening girders

The erection method was the so-called "plane block erection" which handled pre-assembled members as one plane block weighing upto 90 tonnes and was adopted for the stiffening girder erection, because it had several advantages regarding the severe natural conditions and sailing ships.

In the erection of the girders, they will be sequentially extended from the main towers 3P and 4P in both directions of center and side spans. To provide high wind-resisting stability, connections between the members will be made fully rigid by immediately splicing after their erection. The erection procedure will be described below. Blocks transported by pontoon site are unloaded by tripod derricks on the platforms. Temporary storage, arrangement and pick-up of these blocks is performed by the derrick and the towered jib crane. Lifting to the height of the erected girders is conducted by the towered jib crane. The blocks are carried by truck to the extremities of the girders as shown in Fig. 9, and are then sequentially attached at both sides using the travelling derrick.

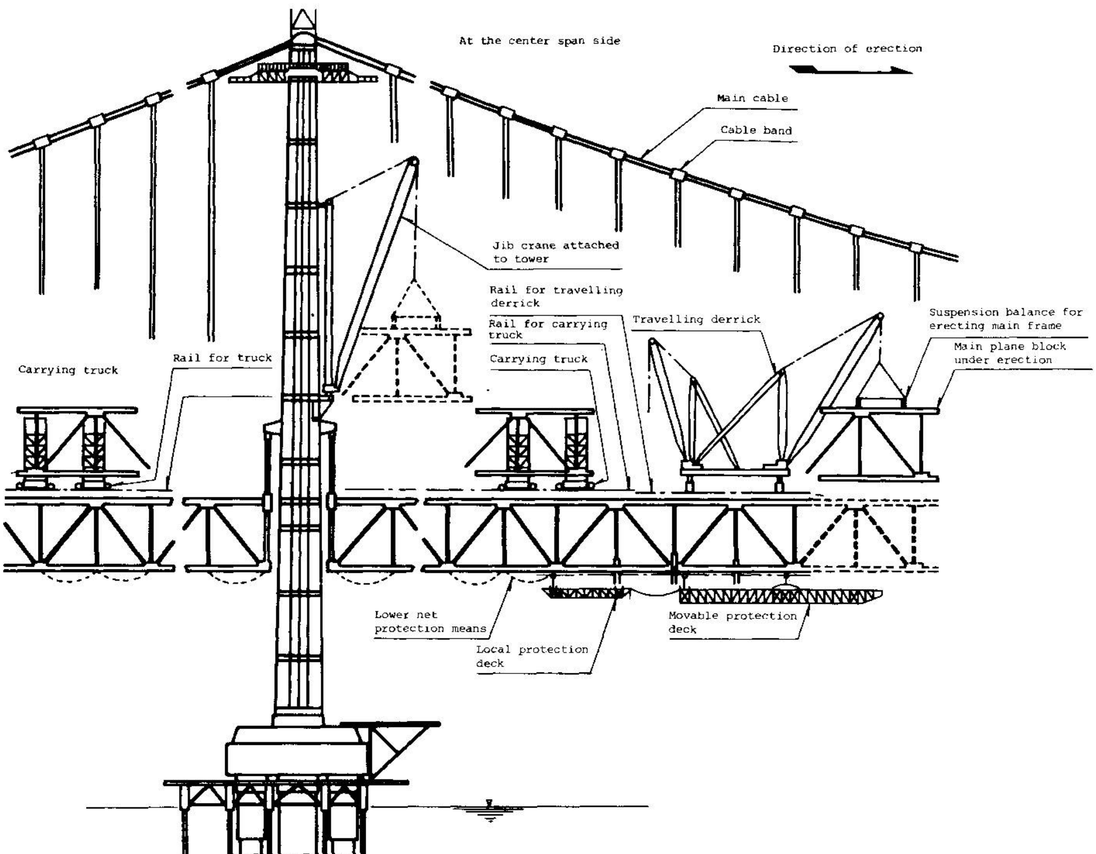


Fig. 9 Stiffering truss

During splicing of the members and the installation of hanger ropes to the erected block, a movable protection deck will be placed just below the erection block. Local protection decks and lower protection nets are also installed at other places in order to assure safety for the workers and to prevent any small tools or bolts from falling. Great precautions will be necessary to prevent any items from falling, because about 600 ships and many fishing boats pass through the strait daily and sight-seeing boats travel frequently around the site to see the famous tidal whirlpool of the Naruto Straits.

At the splice points of the erection block, temporary scaffolds with small steel pipes, wooden plates and chains are provided for fastening the bolts (about 800,000 bolts for the whole stiffening girders). Though the movable protection deck is provided below, installation of the temporary scaffolds itself is dangerous work. Since the girder is 12.5 m high, the work of the joints of the upper chord at such high places shall be reduced to a minimum in the same manner as described for the main tower work.

The main safety measures taken for erection of the superstructure of the suspension bridge have been described above. Though the superstructure work for a long suspension bridge has some peculiarities as large scale, special construction machinery and compound working methods, a unit operation must be handled by each man as the same manner as other ordinary construction works. It is vitally important to plan the appropriate safety measures, based on the risk analysis of accident by considering the character and ability of the workers.

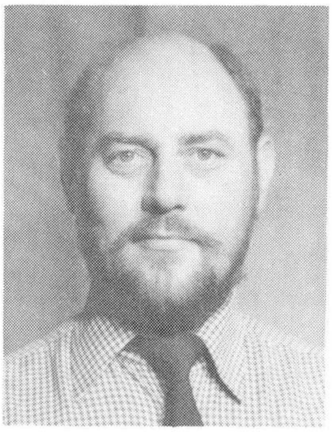
Leere Seite
Blank page
Page vide

Health and Safety in the Humber Bridge Construction, 1973 – 1981

Santé et sécurité sur le chantier du pont suspendu Humber

Gesundheit und Sicherheit beim Bau der Humber-Hängebrücke

Michael SPARKES
Principal Inspector
Health and Safety Executive
Sheffield, England

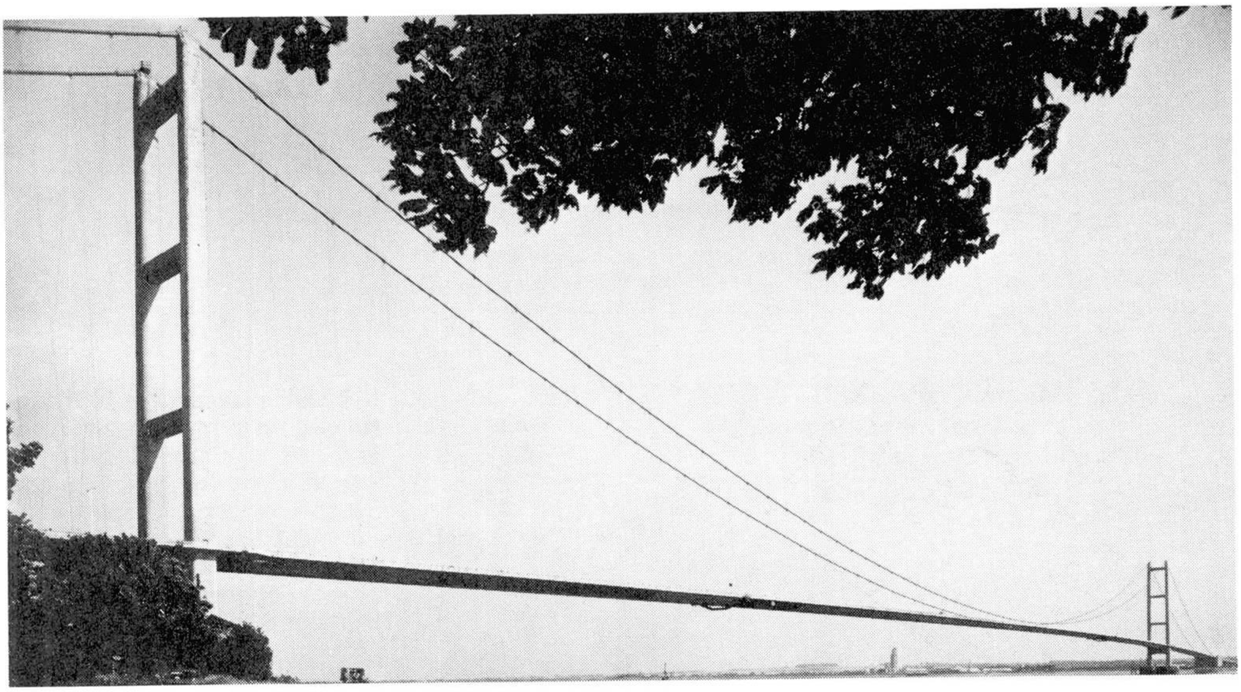


Michael Sparkes, born 1937 took his degree in modern languages and law at Cambridge University, England in 1961 when he joined the Factory Inspectorate. From 1967 he specialised in construction work, inspecting all phases of the erection of the Humber Suspension bridge.

SUMMARY
The construction of the Humber Bridge, UK, with a central span of 1410 m took over 8 years employing a workforce averaging 420 men. At the planning stage already a site safety coordinator was appointed, having jurisdiction for safety over the whole project. The article reviews the phases of construction of the bridge and hazards encountered. Accidents statistics are presented and safety measures recommended.

RESUME
La construction du pont suspendu Humber, GB, avec une portée principale de 1410 m a duré plus de 8 ans et a nécessité en moyenne un personnel de 420 collaborateurs sur le chantier. Dès la phase de projet, un coordinateur de la sécurité sur le chantier a été nommé avec pour tâche d'assurer la sécurité de tout le projet. L'article passe en revue les différentes phases de construction du pont et les dangers encourus. Des statistiques d'accidents sont présentées et des mesures de sécurité proposées.

ZUSAMMENFASSUNG
Der Bau der Humber-Hängebrücke in Grossbritannien mit einer Mittelspannweite von 1410 m dauerte mehr als 8 Jahre, wobei im Mittel 420 Leute beschäftigt waren. Bereits im Projektierungsstadium wurde ein Sicherheitskoordinator ernannt, der für das gesamte Projekt zuständig war. Der Beitrag berichtet über die verschiedenen Bauausführungsphasen und die darin aufgetretenen Gefahrensituationen. Unfallstatistiken werden vorgelegt und Sicherheitsmassnahmen empfohlen.



THE HUMBER BRIDGE

1. INTRODUCTION

This suspension bridge with an unsupported central span of 1,410 metres is located across the tidal estuary of the River Humber in North East England. It has a dual two lane carriageway for vehicles and a cantilevered footwalk and cycle track on either side. The Northern sidespan is 280 metres long and the Southern sidespan is 530 metres, making a total of 2,220 metres. The supporting towers are made of reinforced concrete. There are 16,500 tonnes of steel in the box section deck stiffening girder and 11,500 tonnes in the 2 main support cables. There is 30 metres clearance under the centre of the main span at high water to give adequate clearance for shipping. The tidal flow is at the rate of 5 knots and the river has a rise and fall in level of about 10 metres.

The Bridge took just over 8 years to construct, employing a workforce averaging 420 men, reaching a maximum of 1,000 at one time. The total final cost was approximately £90 million. The Bridge has now been operating for over a year and has been in continual full use.

2. PREPLANNING FOR SAFETY

2.1. The history of bridge construction in various parts of the world reveals a sad story of the heavy toll of lives caused by accidents. At the planning stage of the Humber Bridge it was resolved by all parties, most particularly the Trade Unions, that safety would receive primary consideration. It was decided that an experienced person should be appointed as Safety Coordinator to have jurisdiction for safety over the whole project. Briefly, his main duties were that he would (i) have direct access and would report to the Project or Managing Director in matters of safety; (ii) monitor all work planned and in progress on the site to ensure that correct safety procedures were being followed; (iii) liaise with and advise the safety staffs of all contractors; (iv) maintain contact with Government Health and Safety Inspectors to ensure that all statutory safety requirements were being complied with.

On his appointment in 1973 Mr Drake, the Site Safety Coordinator decided to consult each of the main contractors who were about to commence work to lay emphasis on certain factors concerned with safety which should receive their attention, these factors being:-

2.1.1. That a clear, practical safety policy should be published, declaring the intentions of the management with regard to the safeguarding of the health and safety of their employees whilst at work. It was intended that the safety policy should define responsibilities of the individual members of management and those of the employees in respect of their own safety and that of others.

2.1.2. All employees should be given a thorough safety induction before working on the site.

2.1.3. A balanced safety committee should be formed and should hold regular meetings for the purpose of reviewing the safety performance and for the dissemination of safety information for the forthcoming operations. The proceedings of the safety committee meetings should be published.

2.1.4. The establishment of operational safety codes to cover standard procedures was encouraged, together with the preparation of planned systems of work to cover construction procedures which were out of the normal routine. Some of these will be described shortly.

2.1.5. Temporary works should be given great attention at the design stage in order to plan access and adequate safeguards for working places.

2.1.6. The provision of suitable protective clothing and equipment for the operatives needed careful thought.

2.1.7. Time should be allocated for training purposes, for example to show training films on eye protection, use of cranes etc, and for training in rescue and first aid work.

2.2 All employers agreed to give particular attention to these points. In addition, plans were prepared for the employment of qualified nurses to operate medical centres at 3 separate locations on the project. Experience has shown that in most accident situations, the most critical factor is the time taken to render first aid to the injured person. Accidents invariably occur in difficult locations and under unfavourable conditions. The efforts of well trained rescuers can be nullified and the results to the victim disastrous if the most suitable equipment is not readily available. Each of the 3 medical centres, therefore, was to be equipped with an ambulance, stretchers, resuscitators and all applicable first aid equipment. Emergency rescue and first aid plans were prepared at each separate location on both sides of the river and later each of these was rehearsed regularly in order to give complete and rapid first aid coverage.

2.3. In the United Kingdom we are fortunate in having a comprehensive system of statutes which cover practically every construction process. If the requirements of these statutes are contravened then a Government Inspector can stop the work and can also take legal action in the Courts against the offenders - be they managers or employees. One such Code of Regulations states that all lifting equipment shall be tested before first used and subsequently examined by an expert at regular intervals. This is usually carried out by the inspector of the insurance organisation which has insured the equipment. At the Humber project this system was implemented by identifying equipment which had been examined by a certain colour. Any item which did not bear the correct current colour was removed from service. This practice proved to be a valuable safeguard against the use of faulty or worn equipment which had missed the regular routine inspection.

3. PHASES OF CONSTRUCTION OF THE BRIDGE AND HAZARDS ENCOUNTERED

3.1 Substructure

3.1.1 Anchorages

These are basically large reinforced concrete boxes divided into 2 chambers, each of which incorporates a mass concrete block to which the ends of the main support cables are attached. The Northern anchorage is about 280 metres away from high water mark. It is 65 metres long and 36 metres high, founded in chalk 21 metres below ground level. The Southern anchorage is 30 metres behind the flood bund. This anchorage is 72 metres long, 40 metres wide and 35 metres below ground level on hard clay.

Excavation of the southern anchorage – strulting of longitudinal concrete walls.

Excavation in the chalk for the Northern anchorage was a safe procedure but in the wet clay on the south bank the ground had to be stabilised by sinking reinforced concrete longitudinal walls by Bentonite slurry injection methods to the full depth of 35 metres. Excavation then commenced between the walls which were strutted transversely as the excavation deepened. Both anchorages involved extensive use of scaffolding both below and above ground. Care was taken to ensure that safe access and safe work places were maintained during the use of this scaffolding. Safety committee members were helpful in this respect and reported hazards quickly. Rail mounted Scotch Derricks were used in the excavation process and for raising and lowering materials.

Two fatalities occurred during this phase:-

- A Scotch Derrick collapsed under overload, killing the operator.
- A tipper lorry reversed over 2 men, killing one and injuring another.

These fatal accidents occurred over a period of $2\frac{1}{2}$ years, during which there were 2 site fires, both caused by sparks from welding operations, in which there were no injuries.

3.1.2 Piers

Construction of caissons at the end of the 500 m jetty.

These reinforced concrete structures support the main towers. The Northern piers at high water mark measure 4.4 metres by 16 metres by 11.5 metres high and are founded in chalk 8 metres below ground level. The South piers are located in the river some 500 metres out from the South bank and measure 4.2 metres by 11 metres by 16 metres high, supported on twin hollow caissons about 24 metres in diameter. These caissons were sunk inside steel sheet pile cofferdams by underwater excavation, to a depth of 36 metres below river bed into hard clay. The construction of the caissons involved building a temporary jetty 500 metres long out into the river, capable of carrying heavy traffic. The caisson work involved the use of divers inside and outside the caissons to inspect progress during the sinking operation. Careful thought had to be given, in addition to the hazards involved in the diving operation, to the conventional problems of safe access and safe place of work. This involved the establishment of rigid rules for working over water where conventional safe working platforms could not be established,, such as the provision of safety lines to which harnesses could be attached, the use of life jackets at all working positions where men were liable to fall into the water, and at all times when travelling by water and working from small craft. It also included the provision of adequate illumination for work which was done at night time. The accidents which occurred during this phase included several incidents of men falling into the water, usually when travelling from ship to shore or vice versa. There was one fatal accident during this phase also:- a small work boat fouled the mooring cable of a pontoon and was overturned by the fast current, which swamped the boat. Four of the men on board were saved, but the skipper of the boat was trapped in his cabin and drowned. This accident occurred as darkness approached. Thus rendering unsuccessful the helicopter search for the skipper's body.

3.1.3 Towers

Each tower consists of 2 tapers vertical reinforced concrete legs braced together with 4 reinforced concrete horizontal portal beams. The legs which were built simultaneously by continuous slip form method, are hollow columns 155 metres high, each with a central access shaft. Their construction work proceeded continuously with 2 x 12 hour shifts for 3 months, climbing at a rate of 4 inches per hour. Access to the mobile platform for personnel was by means of a rack and pinion hoist, whilst materials were raised by a rope guided hoist and by climbing cranes. The principal hazard during this phase was that of falling materials which was countered by enclosing the working platform completely by a mesh fence 1.5 metres high and by providing safety nets and material nets of 6 mm mesh underneath the platform. The portal beams were constructed on falsework which was supported by a suspended steel truss weighing 70 tons, working from the top downwards.

The accidents which occurred during this phase included an electrician whose toes were guillotined during the erection of the rack and pinion hoist, a labourer whose safety helmet and head were split by falling concrete and a dangerous occurrence when a portal beam rig fell 30 metres to the ground before the start of work. This last incident fortunately caused no injuries to personnel.

3.1.4 Fabrication

During the construction of the substructure the box units which make up the deck stiffening girder were being fabricated at a separate location on the river bank nearby. Each unit consisted of stiffened steel plate panels welded together to form a hollow box 22 metres wide, 18 metres long and 4.5 metres deep with 3 metre wide panels cantilevered from each side. Cross girder webs in the form of diaphragms were fitted internally at 4.5 metre centres. 124 boxes were needed to make up the deck girder, the average weight of which was about 130 tonnes. A considerable open space easily accessible to the river was required in which to set up the fabrication area which included:

- A reception area for the raw steel plate.
- A shot blasting and painting factory.
- A further storage area for the painted steel.
- An assembly area big enough to assemble and weld the boxes and match them

end to end.

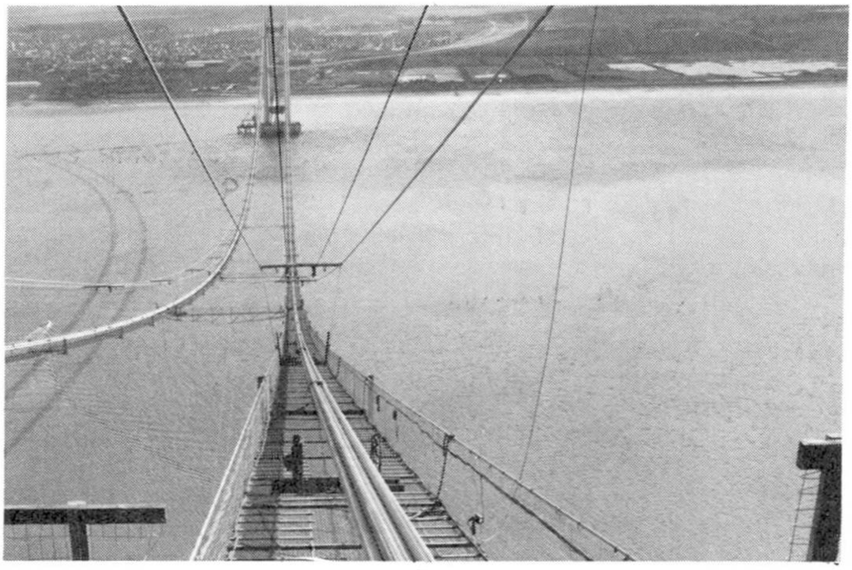
- A storage area for the assembled boxes.
- An overhead travelling gantry to move the boxes out over a main line railway prior to transportation by water to the bridge site 2 miles upstream.

The fabrication operation employed 250 people, including welders, crane drivers, labourers and painters, for a period of 4 years. The safety problems encountered in the fabrication yard were those common to the manufacturing industry and shipyards, namely the handling of heavy loads by crane and vehicle, welding in confined spaces, access inside boxes and risks to the eyes and lungs.

The most common accidents in the fabrication yard were falls of persons caused by tripping or stumbling over obstacles or slipping on wet steel surfaces, with resultant injuries to backs and limbs. Particular attention had therefore to be paid to the provision of suitable walkways and steps and to site tidiness. Precautions were taken to extract toxic welding fumes, shot blasting impurities and paint fumes, and very little trouble was experienced as a result. There was one fatal accident in the fabrication yard when a steel plate fell from a crane on to the man who had slung it. There was also one cabin fire, which resulted in considerable devastation, but no injuries.

3.2 Superstructure

3.2.1 Cable Spinning



Mainspan cable part way trough spinn..g process.

Each cable comprises 14,948 parallel galvanised drawn 5mm diameter wires, divided into 37 strands each of 404 wires.

To construct these a working platform was required at cable height between the anchorages across the Bridge. A footbridge or "catwalk" was erected with an overhead tramway at a similar level to enable pulleys to travel backwards and forwards across the river to pull individual cable wires into place. Tower top cranes were required to lift all components to cable level, including the tower top saddles.

Initially, single cables were taken across the river and then work cars were erected on to these cables to erect the tramway beams and footwalk transoms. Following this mesh panels were pulled out from the tower tops to the centre of the span and down to the anchorages. Finally, the cable spinning could commence with men stationed at intervals across the bridge to receive the wires. Two 8 hour shifts were worked, each shift involving approximately 70 men. The spinning process lasted nearly 2 years.

The principal hazards anticipated during this phase of the work were:-

- Men falling - this was countered by ensuring that the workplaces were all adequately protected.

- Materials falling - this was catered for by ensuring that working platforms were fully boarded with toe boards and mesh side screens, with provision for boxes for small material which could fall through the openings in the mesh of the catwalk.

- Injuries from handling moving wires - this was catered for by ensuring that the operatives wore suitable protective clothing and used guide sticks wherever possible.

- Injuries from whiplash, from a wire suddenly being brought under tension after being allowed to go slack. This was catered for by ensuring adequate communication between the control position for the spinning operation and each individual station on the mesh.

- Adverse effects on the operatives from exposure to severe weather conditions. Wherever possible, protection from the wind was provided at the wire handling points, with all operatives provided with heavy duty protective clothing.

- Incidents which were liable to occur through lack of coordination between control and operating points. This was catered for by the communication system referred to above which included direct telephone system in addition to the short wave radio voice transmission system used throughout the project.

The spinning process was completed without serious accident or incident. The health and welfare of the operatives was provided for by the establishment of kitchens and mess rooms at each tower top, supplemented by food and drink being distributed across the catwalk by men with backpacks. One problem relating to the health of the operatives which occurred during the spinning process was that of atmospheric pollution from a nearby factory chimney which was discharging nitrous oxides and sulphur dioxide from the factory process. In certain weather conditions the fumes tended to float at cable height, causing extreme breathing irritation and disturbing the spinning operatives. Atmospheric checks were carried out over a considerable period and although the concentrations found were slight and well below the Threshold Limit Value, they did nevertheless affect the workers. Fortunately the prevailing weather conditions resulted in very few occasions when work was seriously affected.

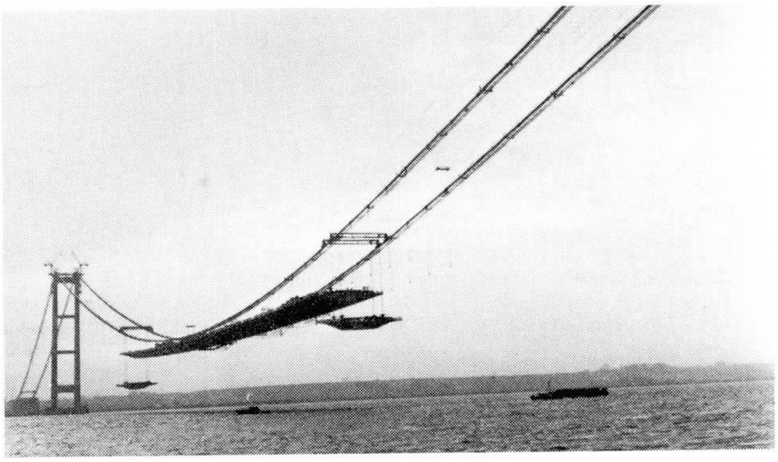
3.2.2 Cable Compaction

Once all the wires had been laid and formed into their strands the total cable was formed into a circular shape by a compaction machine. Cable clamps were then fitted to the cable and the suspension ropes for the deck boxes were lowered through the catwalk and then attached to the cable clamps. Care had to be exercised at this stage when the mesh forming the catwalk was cut to enable suitably sized slots to be formed for the lowering of the suspension cables. The lowering of the cables itself had to be carefully controlled in order to avoid losing the cable through the hole once there was sufficient weight of cable hanging free.

3.2.3 Deck Erection

A lifting carriage of 2 lattice beams spanning between and rolling on the main cables was positioned ready to lift the deck boxes up to the cables for attachment to the suspension hangers. Four winches were located at the base of each tower to operate the lifting tackles attached to the carriage. The deck boxes were lifted from the assembly yard down river by a gantry over the main railway line and moved out on to special pontoons in the river at high tide and then ferried upstream to the bridge site and lifted into place.

The safety measures which were taken for this part of the operation, as with the spinning of the main cables and lifting of the main Caswell cranes to tower top, comprised principally a fully detailed predetermined system of work which clearly defined each stage of the erection. Every man was schooled in his particular role in the operation. Supervision had to be of the highest order since any slight mistake in this type of operation could and did nearly proove fatal.



Erection of the main span during february 1980. Each box is 18.1 m long by 28.5 m wide (including the footpaths along each side). And weighed approximately 140 tons.

After each box was lifted into place and pinned in position on to the correct hanger, the lifting carriage had then to be moved up the cable to its new lifting position by hauling it on its rollers along the cable. The 4 main lifting winches at ground level were used for this purpose, being attached directly to the lifting carriage by tag lines. During the final move of the Northern sidespan carriage the tag lines failed and the carriage fell from the cable through the suspended deck 120 metres below, causing damage to the suspended boxes and severely injuring 2 men on the catwalk. The hangers, cables, pins and boxes did not fail and remained suspended with no damage, although the temporary connection between the 2 box sections affected was broken, allowing the boxes to tilt to an alarming angle. The cause of the accident is believed to be the failure of the several Crosby clamps attaching the haul line to a tag line on the carriage. It would appear that they were not tightened sufficiently to withstand the strain of hauling the 25 ton load up the cable and over the cable clamp on the steepest part of the cable and one side pulled out causing the carriage to roll back down the cable and fall off, dragging the second carriage with it. The winch operators immediately below heard the noise above and ran before the falling debris smashed down on to the 4 winches.

Besides paying meticulous attention to all lifting and hauling tackle in this type of operation, we must bear in mind that we are operating at a critical height above ground and also much of the time over water, so that all practicable measures must be taken against the risk of falling and drowning. On the Humber project arrangements were made for rescue by men with stretchers for the work done on the catwalk, supplemented by helicopter rescue for casualties in the main span. Simulated rescue operations were organised and practised during this phase.

Welding operations started as soon as the deck boxes were in place with all the joints, both inside and outside, being welded. Extraction of fume from inside the box sections was essential. All the lighting and power supplied on the deck was at 110 volts. Welding was by electric arc method. There were some oxygen and propane burners used but these were not allowed inside the boxes. Radioactive sources were kept on the site for use in radiographic checks on the welds, most of which were done when the main workforce had finished for the day. The use of radioactive sources was strictly controlled and each area was cleared and barriers erected by the specialist contractors before any source was energised. The use of radioactive isotopes in this situation is of course governed by a code of regulations enforced by the Factory Inspectorate.

3.2.4 Red Lead Pasting and Wrapping

Whilst welding progressed, work in other areas proceeded simultaneously - cable pasting with red lead paste followed almost immediately by wrapping with soft steel galvanised wire. This task employed a workforce of 100 men working two 8 hour shifts. In this instance the use of red lead, which involved the risk of ingestion and absorption of lead into the bloodstream, the system of work included strict personal hygiene measures which the workforce were obliged to adhere to for their own protection and the protection of other persons. The system of work was prepared and published and the workfoce was trained and instructed in the methods expected of them before they started work In addition, extra clothing was provided to enable sufficiently frequent changes. Separate changing, washing and feeding locations were provided as close as possible to the sites of work. Since lead poisoning is a very real threat to health and because it can quickly enter the bloodstream via the lungs and stomach, the precautionary measures regarding smoking, eating, working and changing of clothes together with the segregation from workers separate from the lead process, had to be strictly enforced. Each man working with the red lead had a blood sample taken at regular intervals so that the level of lead could be monitored and an individual record was maintained for each man. Only one inveterate smoker of hand rolled cigarettes had to be removed from the job when his blood lead level reached 80 microgrammes of lead per 100 ml of blood - the predetermined level of concern. The blood lead levels of all workers increased from the normal average of 10-15 microgrammes per 100 ml to 30-50 level, but each man was told his blood lead level result and was aware of his own increase or decrease. It was noticeable that the more hygienically conscientious men maintained the lowest levels. As cable wrapping progressed the surplus red lead was removed from the cable in readiness for the 5 coats of paint to be applied by hand brushwork. Meanwhile, below, the road surfacing of the steel deck was progressing and the final additions of concrete infill to the anchorages were placed.

3.3 Site Clearance

Finally came the dismantling of the catwalk, tower top cranes, river gantries, temporary jetties etc. In these procedures again it was necessary to prepare systems of work which were fully understood by the men and closely supervised by management. In this type of dismantling work it is all too easy to allow the person in charge or the foreman to improvise his system and to rely on his experience instead of working to a preplanned system. Such improvisation works very well on most occasions but on others it can lead to disaster, as on one occasion when dismantling one of the tower top cranes which had been lowered safely to the ground. A second smaller crane was in use to strip the heavy components and a planned system of work with drawings had been prepared. Unfortunately the plans were not followed and improvisation occurred which resulted in the collapse of a 70 ton crane whilst it was under load. Luckily again no-one was injured, although a considerable amount of damage was done to the crane.

Other hazards and precautionary measures that had to be taken during construction were:

3.3.1 Confined Spaces

In certain parts of the bridge there are areas designated as confined spaces- ie areas underground or under water which do not have natural or forced ventilation and which may remain sealed for long periods. Such areas occur at the bottom of the caissons and underneath the anchorage foundations. In these places there is equipment such as pumps installed which from time to time need maintenance and therefore access is required. In such places it was ruled that atmospheric testing for oxygen deficiency or ingress of methane or carbon monoxide should take place before entry and an "operational safety code" was devised which had to be followed by workers or others who might have to enter such places.

3.3.2 High Voltage Electricity

Similarly, in places where high voltage equipment was installed the "operational safety code" required a "Permit to Work" system before entry could be gained, thus ensuring that proper authorisation and adequate safeguards were observed before and during entry.

3.3.3 Fire Protection Systems

A similar situation exists following the completion of the construction of the bridge in such places as the portal beams spanning between the supporting towers, where high voltage permanent electrical equipment is installed in a relatively confined space. In these areas there are automatic total flooding fire protection systems which can prove dangerous to human life if the proportion of extinguishing vapour is not carefully controlled. In the case of the Humber Bridge the proportions are below suffocation level, but nevertheless a system of key control is provided to ensure that persons within the confined space cannot be subjected to the sudden shock of the noise created by the automatic discharge of a Halon fire protection system, nor can be overcome by a concentration of vapour.

4 ACCIDENT STATISTICS

From the beginning of the project the Site Safety Coordinator decided that a regularly produced summary of accident information covering all workers on the project and giving figures and a performance graph would be of value The summary was designed to give a ready indication of accident trends, to show which was the most prevalent type of accident and in what kind of operation it occurred. It would also include the type and severity of injury received and the increase or decrease in volume etc. All accidents were included in the summary, even those not involving "lost time", mainly because nearly every minor accident could have been major with severe results, and in addition even minor accidents and light injury involved the first aid and rescue machinery The statement was published monthly and posted prominently throughout the project for the information of all the workforce. Statistics for each contractor were recorded separately on the same statement so that an immediate comparison of accident frequency for the period could be drawn. The benefit to management of this publication was that "high risk" activities could be identified quickly and the system of work or the equipment changed accordingly to eliminate the risk. Greater protective measures could be introduced as a result to improve safety and reduce the accident rate. Additionally, by reference to the types and severity of injury which was also recorded, the manpower wastage rate could easily be assessed.

The statement also had the effect of retaining the state of safety awareness among the workers who were able to compare their own safety performance against that of a contractor.

4.1 Facts and Figures

- Total (approx) man hours worked, 8 years	7,870,000 man hours
- Monthly Average	81,980 man hours
- Number of men employed (average) Monthly	424 men
- Average one man monthly	193 hours
- Total all accidents major & minor, 8 years including total of lost time (more than 3 days), 8 years	4,546 348
- Average all accidents monthly	47.3
- Average lost time 3+ monthly	3.6
- Average Incidence rate monthly; all accidents per 10,000 m/hrs over 8 year period	5.8
- Fatalities, 8 years	4

Cranes 2, Drowning 1, Transport 1

5 HIGH RISK ACTIVITIES

From the records and statistics compiled it became readily recognisable that activity risk could be identified in the following order of priority:

- Steel erection (including use of cranes)
- Dismantling or demolition
- Painting
- Scaffolding
- Falsework
- Marine work
- Excavation (including use of heavy transport).

The investigation of every serious accident identified the following causes of the majority, not necessarily in order of priority and not necessarily the sole cause:

5.1 Human Causes

- Haste, or taking changes or short cuts to speed the job.
- Lack of knowledge of the procedure or equipment.
- Lack of concentration or appreciation of the risk.
- Poor or inexperienced or absence of supervision.
- Not working to a prepared or planned system or method, but perhaps relying on the experience of the worker who will improvise to get the job done.

5.2 Material Causes

- Structural or physical failure of material or equipment.
- Unsafe or faulty tools or equipment.
- Misused or misapplied equipment.
- Lighting.
- Weather.
- Lack of, or insufficient, equipment.

6 SAFEGUARDS AGAINST ACCIDENTS

6.1 For Management

- It is vital to establish a clear, practical safety policy with responsibilities well defined and allocated to appointed personnel.
- Safety should be considered at the planning stage of every operation.
- Well organised safety meetings should be held regularly and all business should be efficiently followed up.
- Adequate supplies of serviceable tools and equipment should be provided.
- Systems of work should be established for each operation.
- Training in systems and anticipated operations should be encouraged and organised.
- Supervision of each aspect of the work and inspection of the equipment and results should be thorough and constant.

6.2 For Operatives

- They should be fully familiar with the planned system of work and should be trained and instructed in that method.
- They should be aware of the need for safe access to their place of work and to the safety of that place. They should be prepared to draw attention to defects in access and place of work safety and arrange rapid remedies where possible. They should be aware of the standard expected of the tools and equipment which they are expected to use and should draw deficiencies that they notice immediately to the attention of their supervisor, so that a replacement or repair can be effected. They should also be aware of the effect of their work on other people in the vicinity and organise themselves so that they present the minimum hazard.
- In situations where it is necessary for operatives to wear personal protection, whether it be of the head, eyes, ears, feet, hands, lungs or general body, they should be made aware of the reason for the use of the protection and should co-operate in the use of the personal protective equipment.

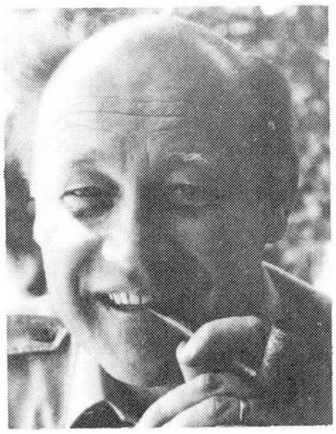
The cost of safety during the construction of the Humber Bridge was approximately 1% of the total expenditure on the project.

Health and Safety in Swiss Tunnelling

Santé et sécurité dans la construction de tunnels en Suisse

Gesundheit und Sicherheit im Tunnelbau in der Schweiz

Robert FECHTIG
Professor
Swiss Fed. Inst. of Technology
Zurich, Switzerland



Robert Fechtig, born 1931, got his civil engineering diploma at the Swiss Federal of Technology (ETH) in 1956. Two years in water works construction in Sweden. Two years as a research assistant at the ETH. In construction firm Zschokke 1960 – 1981, active in the field of large civil engineering projects and especially subsurface projects. Professor of construction engineering and management at the ETH since 1981.

SUMMARY
The introduction shows the basic law for Swiss accident protection; its structure is given and the specific laws, ordinances and guidelines for tunnelling accident protection are explained, as well as the financial resources and the whole organization. Four actual examples illustrate the problem of tunnelling accident protection and conclusions are made.

RESUME
L'article présente les bases légales de l'assurance suisse contre les accidents professionnels. Il mentionne les directives, règlements et lois dans le domaine de la prévention des accidents lors de la construction de tunnels. Il mentionne également les moyens financiers et l'application de ces règlements. Quatre exemples choisis illustrent le problème de la protection des accidents dans la construction des tunnels.

ZUSAMMENFASSUNG
Einleitend werden die gesetzlichen Grundlagen des schweizerischen Unfallschutzes erläutert und deren grundlegender Aufbau dargestellt. Es folgt die Nennung von Richtlinien, Verordnungen, Gesetzen für den Bereich des Untertagebaues unter Einbezug der finanziellen Mittel und der Art und Weise der personellen Durchführung. Anhand von vier ausgewählten Beispielen des Tunnelbaues wird das Thema abgerundet und zum Gesamtproblem Schlussfolgerungen gezogen.

1. INTRODUCTION

Each country has its own way of organizing its activities towards better health and safety of its workers and of providing adequate accident prevention during the works in progress. Let me present a short general survey of health and safety in Switzerland and then let me deal with the specific questions concerning tunnelling.

BREAK DOWN OF THIS PRESENTATION

- BASIC LAW FOR SWISS ACCIDENT PROTECTION
- STRUCTURE OF THE SWISS ACCIDENT PROTECTION
- BASES FOR TUNNELING ACCIDENT PROTECTION
  - LAW / ORDINANCES / GUIDELINES
  - FINANCIAL RESOURCES
  - ORGANIZATION
- ACTUAL EXAMPLES OF TUNNELING ACCIDENTS PROTECTION
- CONCLUSIONS

Fig. 1
Break-down of this presentation

2. BASIC LAW FOR SWISS ACCIDENT PROTECTION

Since 1911 the Swiss law provides a particular basis for health and safety at work.
The law in question is called SAIA (Sickness and accident insurance act).

The law stipulates (in Art. 65.1) that all company owners or employers are responsible for protecting their employers from accident and occupational diseases.

The Government had to create the necessary organizational structure to ensure the implementation of the accident protection act.

3. STRUCTURE OF THE SWISS ACCIDENT PROTECTION

In 1918, the Swiss Accident prevention agency was established in Lucerne. This insurance organization is not a Federal agency, but a public company for the purpose defined in the sickness and accident insurance act. The concept of the structure and the procedures of this organization are described in both the sickness and accident insurance act and the organizational directives of the Swiss accident prevention agency Board.

ORGANIZATIONAL STRUCTURE

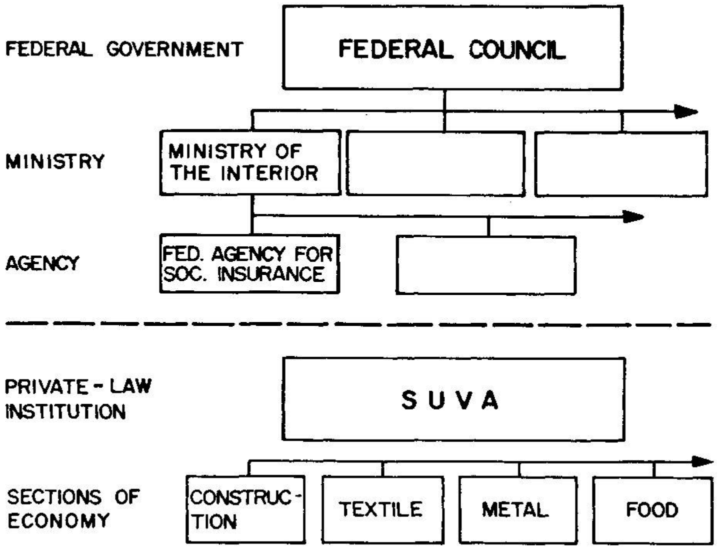


Fig. 2
Organizational structure (according to the sickness and accident insurance act)

GEOGRAPHICAL DISTRIBUTION

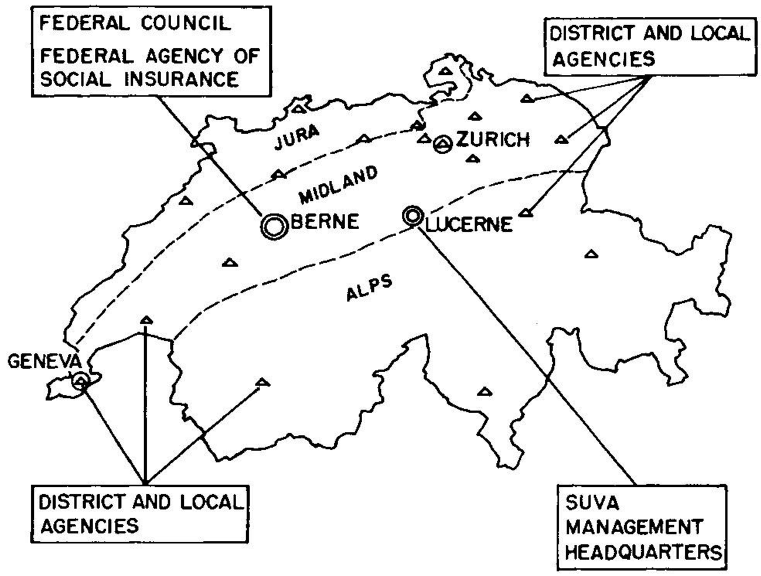


Fig. 3
Geographical distribution

RESPONSIBILITIES/PARTICULARITIES

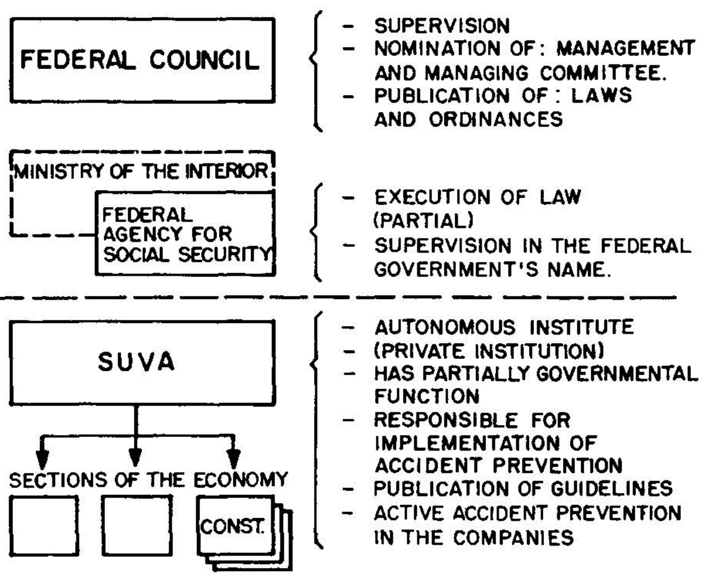


Fig. 4
Responsibilities/Particularities

4. BASIS FOR TUNNELLING ACCIDENT PROTECTION

4.1 Law, ordinances, guidelines

Many ordinances and guidelines were created and became effective within the last seventy years. They are based on the sickness and accident insurance act. The rapid technical development during the last thirty years, however was responsible for most of them.

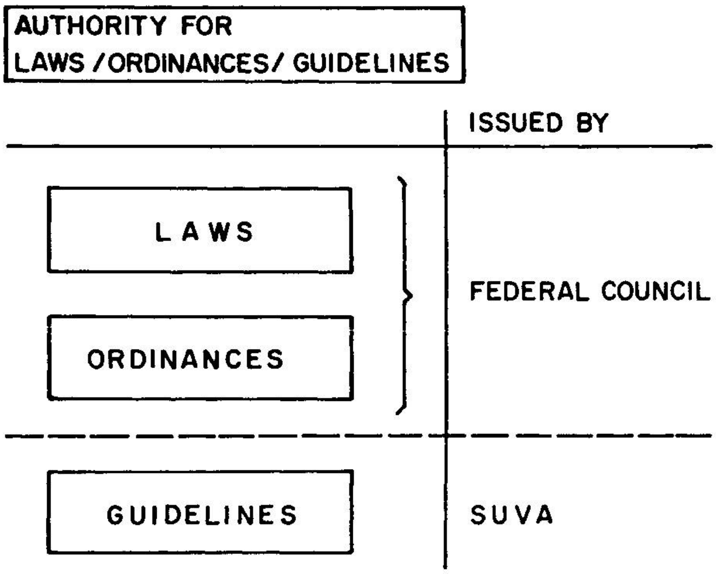


Fig. 5
Authorization for laws, ordinances and guidelines

TUNNELLING IMPORTANT H+S DOCUMENTS

SUVA FORM Nr.	DATE OF LAST ISSUE	L	O	G	LAW / ORDINANCES / GUIDELINES
1382	15. 2.57		X		CABLE CARS
1420	22. 6.51		X		CRANES
1425	08. 9.48		X		SILICOSIS
1471	25. 3.77	X			EXPLOSIVES
1484	FEB. 77			X	VENTILATION
1497	NOV. 72			X	FIRE AND EXPLOSIVES (GAS)
1520	23.12.60		X		OCCUPATIONAL DISEASES
1574	JULY 71			X	EARTHMOVING + TRANSPORTMACH.
1796	8. 8.67		X		ACCIDENTS
1845	JULY 77			X	CRANES
1923	JULY 71			X	SILICOSIS
1974	FEB.73				HUMID HOT CLIMATE
1977	FEB.78			X	ACCIDENTS

Let me summarize some of the important documents for tunnelling:

Fig. 6
Important documents for the protection of tunnelling accidents

4.2 Financial resources

Like any other insurance company, Swiss accident prevention agency needs financial resources for achieving its objectives.

The law stipulates that Swiss accident prevention agency shall collect premiums to pay for the settling of insurance claims and administration costs.

The premium rates vary according to the professions and the risk of the workers involved. The rates are calculated at %o-part of the total amount of wages.

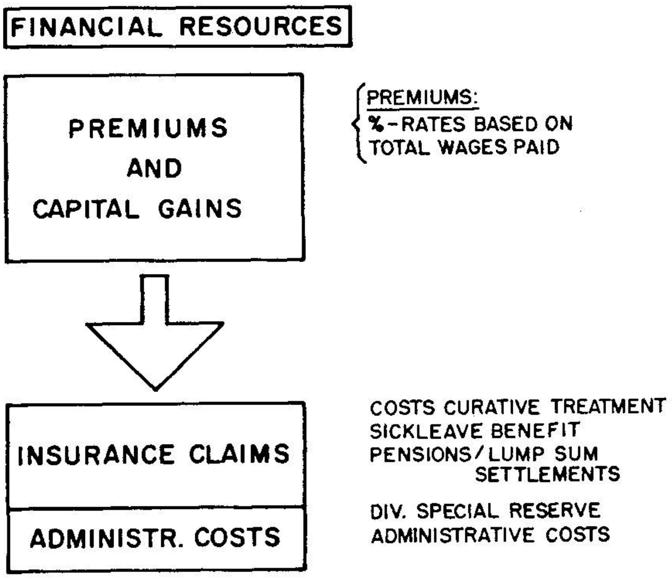


Fig. 7
Use of financial recources

A survey over the whole of Swiss accident prevention agency shows the following figures, if we intend to compare the total of Swiss accident prevention agency's field of activity with its construction part.

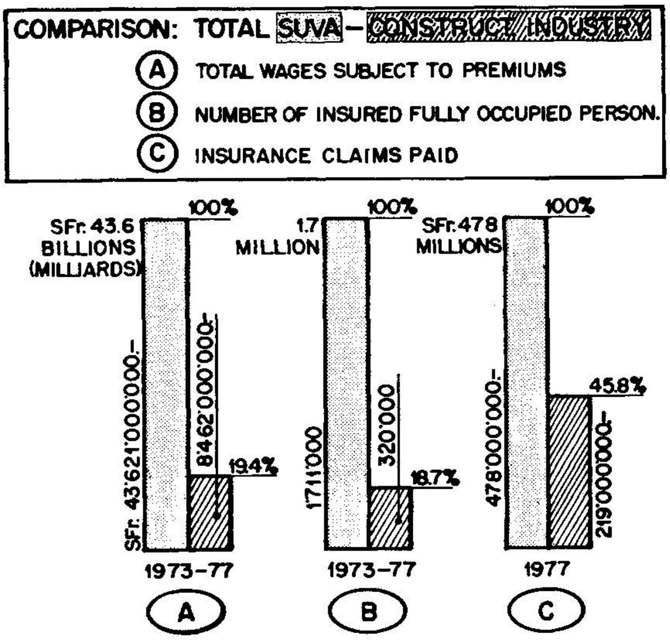


Fig. 8
Comparison of Swiss accident prevention agency as a whole with the construction industry:
- total wages subject to premiums
- number of insured fulltime employees
- insurance claims paid

How much is the amount of premiums paid by the construction industry? Until 1971, each company had to pay at an individual rate (percentage of the total wages paid) according to the risk appraisal of Swiss accident prevention agency. Since 1971, all companies of the construction industry are paying at the same rate of 4,3% of the total wages. However, companies which do not fulfill their obligations of accident prevention on construction sites and act against regulations, will have to pay a surcharge of 0,5 to 1,5%. This increased rate will be imposed regardless of the number of accidents happening on the sites of that company.

A tunnelling construction company is paying premiums in the same way companies engaged in the construction of bridges, hydraulic works, building or roads are paying theirs.

4.3 Organization

SUVA's staff (S.A.P.A.) is made up of specialists of a great number of different professions.
Each sector is responsible for enforcing the ordinances in their field and for convincing the various companies of the Swiss industry to apply the corresponding guidelines.

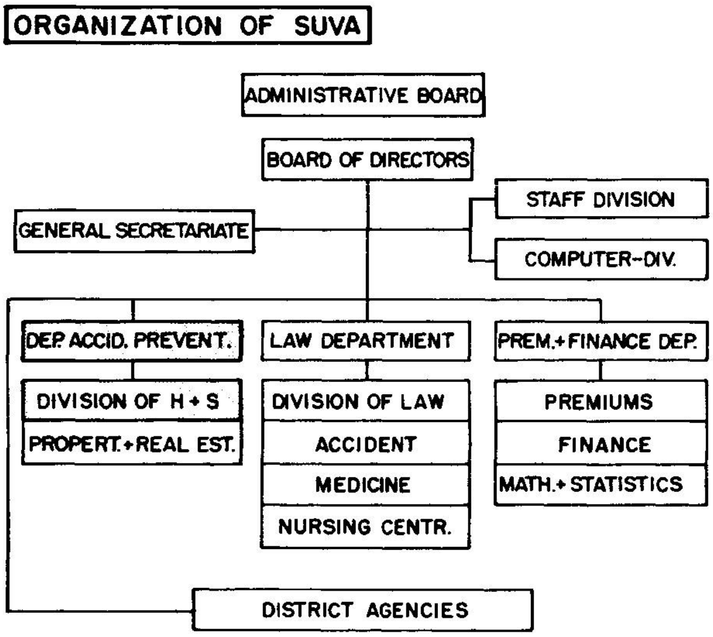


Fig. 9
Organization of SUVA (SAPA)

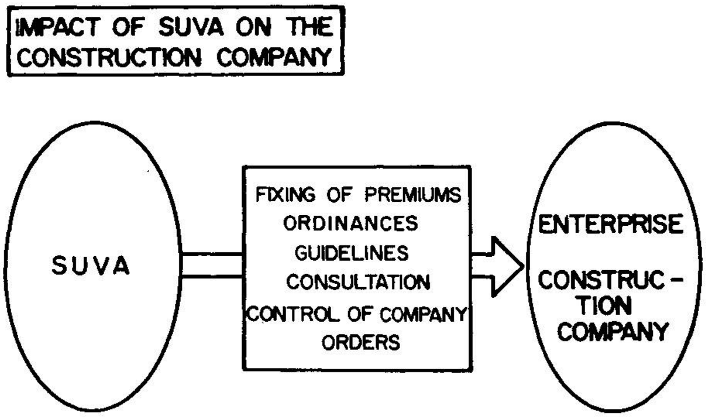


Fig. 10
SUVA's impact on the construction company

SUVA (SAPA) officials are checking both privat and public companies in their field with regard to the health and safety protection of their employees.

There are no detailed accident statistics in the construction industry - this means that an exact basis for specific accident prevention doesn't exist in this branch of industry.

Apart from surveys of the common problems of accident prevention in tunnelling (such as protection from falling stones or rocks, control of dust, the use of explosives) various Swiss galleries and tunnels have been systematically investigated during the last years as to the existence of Radon. Radon was found in zones of cristalline rock in the Alps. Therefore, the question of ventilation has to be studied very carefully.

5. CURRENT EXAMPLES OF ACCIDENT PREVENTION IN TUNNELLING

5.1 Historic development

Due to the very complex geology of Switzerland (over a region of 41'300 km2) the development of tunnelling systems shows great diversity.

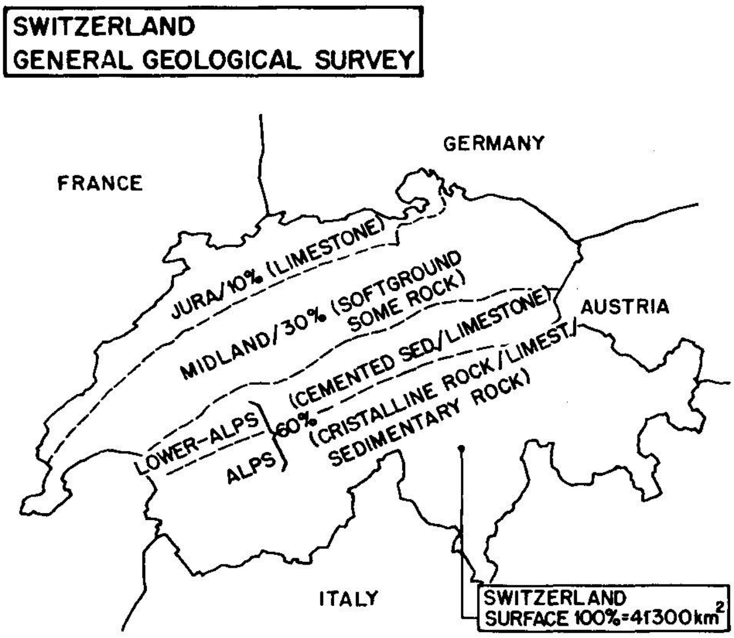


Fig. 11
Geological survey of Switzerland

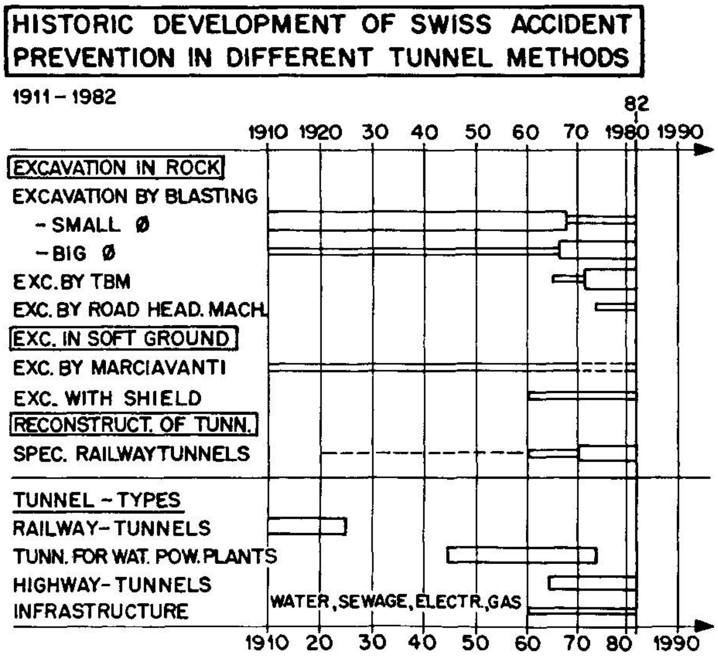


Fig. 12
Historic development of Swiss accident prevention of different tunnelling methods

During the last seventy years the main aspects of accident prevention have changed continously along with the development of tunnelling construction methods.

5.2 Current

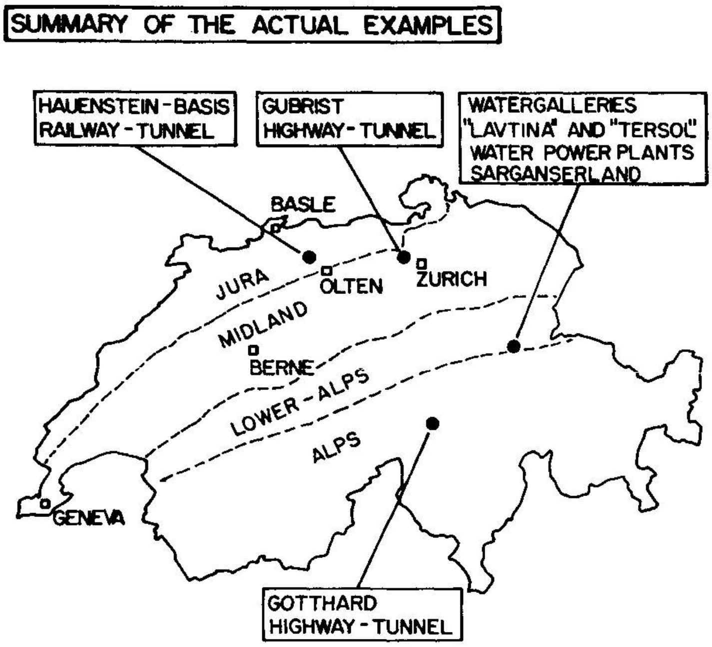


Fig. 13
Survey of current examples

a) Tunnelling in extreme parts of the Alps - water gallery "Lavtina" and "Tersol" of the waterpower plant "Sarganserland"

- Gallery Lavtina: Excavation ø 3.50 m with TBM
  Length 6'000 m

- Gallery Tersol: Excavation 6 m2 conventional excavation
  Length 1'300 m

WATER POWER PLANT SARGANSERLAND
WATERGALLERY "LAVTINA" UND "TERSOL"

MAIN DANGERS:

AVALANCHE (IN WINTER):
- DANGER FOR ROADS AND ACCESS ROADS
- DANGER FOR OFFICES / LODGEMENT / WAREHOUSE

HIGH TENSION (IN THE GALLERY 6000 VOLT):
- SECURITY FOR THE ELECTRICAL INSTALLATION

GALLERY SECTION (WITH TUNNEL BORING M.):
- LIMITED SPACE
- DURING MACHINE OPERATION NO WALKING IN THE GALLERY
- DANGER OF ROCK BREAK DOWN (BY 1000m ROCK-COVERING)

FIRE:
- DANGER OF FIRE FOR TRANSFORMER
- DANGER OF FIRE FOR OFFICE / LODGEMENTS

Fig. 14
Main dangers of the Lavtina site

b) Tunnelling in the Alps

Gotthard Highway Tunnel / National Highway N2

Length	16'322 m
Excavation section	
savety gallery	6,5 m2
Main tunnel north	69 - 86 m2
south	83 - 96 m2
Excavation method	blasting
Vertical- and inclined shafts (for ventilation): 4 shafts	
Length	304 - 844 m
Excavation diameter	6,2 - 7,7 m (circle)
Excavation method	by TBM

GOTTHARD HIGHWAY – TUNNEL

MAIN DANGERS:

AVALANCHES (IN WINTER):
- DANGER FOR APPROACHES
- DANGER FOR TECHNICAL INSTAL. (OUTSIDE THE TUNNEL)

BREAK DOWN OF ROCK:
- BY EXCAVATION IN THE WHOLE SECTION
- BY EXCAVATION IN CHAMBERS
- IN VERTICAL AND INCLINED SHAFTS

DANGER OF FALLING OFF:
- IN VERTICAL AND INCLINED SHAFTS
- ON HIGH FORMWORK CONSTRUCTIONS

DANGER OF COLLISION:
- BY THE TRANSPORT OF MUCK
- BY RESTRICTION OF PASSAGE

DANGER OF FIRE:
- FOR LODGEMENTS / OFFICE / WAREHOUSE

Fig. 15
Main dangers at the Gotthard site

c) Tunnelling in the Swiss Midland Area

Gubrist Highway Tunnel:

Length (2 tubes at 3'300 m)	6'600 m
Excavation section	103 m2
Excavation method	by TBM

GUBRIST-HIGHWAYTUNNEL

MAIN DANGERS:

- HANDLING OF HEAVY MACHINE-CONSTR-PIECES
- HANDLING OF PREFABRICATED PIECES (ON STORAGE YARD AND IN TUNNEL)
- HEAVY TRANSPORT (MUCK AND PREFABRICATED PIECES)
- PASSAGE-RESTRICTION DUE TO THE TUNNEL FORMWORKS
- HIGH TENSION FOR TUNNEL INSTALLATION
- DANGER OF FALLING OFF:
  - THE TRAIL-CONSTRUCTION OF TBM
  - HIGH TUNNEL FORMWORK
  - THE FORMWORK OF THE SLAP

Fig. 16
Main dangers at the Gubrist site

d) Reconstruction / Restauration of tunnels

Hauenstein Basistunnel

Doubletrack railway tunnel of the Swiss Federal Railways (SBB)
Length 8'000 m

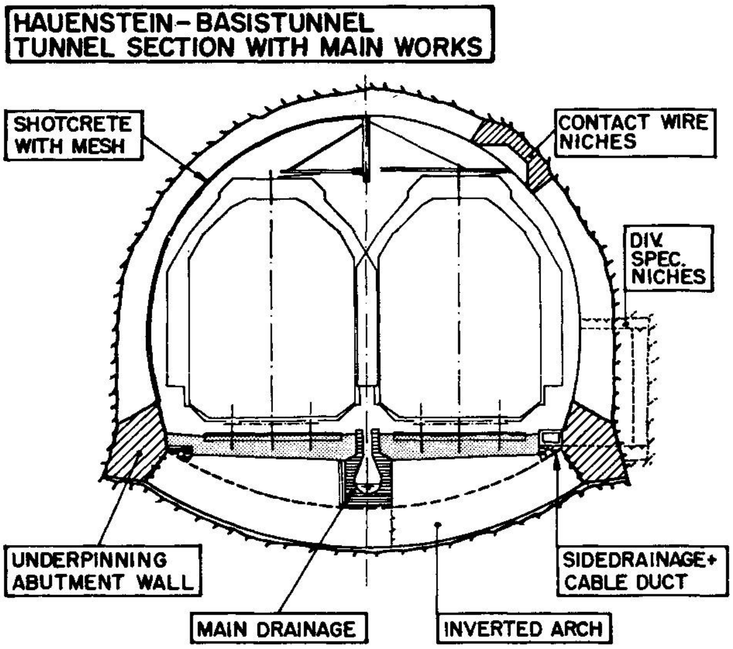


Fig. 17
Tunnel section showing the principal operations

HAUENSTEIN - BASISTUNNEL
SWISS RAILWAY TUNNEL

MAIN DANGERS:

- PASSING BY OF SCHEDULED TRAINS
- LIMITED SPACE FOR MACHINE INSTALLATIONS
- DUST / DIMMED SIGHT OF SIGNALS
- HIGH TENSION (15000V) ON THE ORDINARY RAIL
- HIGH TENSION FOR THE TUNNEL INSTALLATIONS
- DANGER OF FIRE (TRANSFORMER)
- SECURITY FOR THE ORDINARY RAILS DURING BOTTOM EXCAVATION

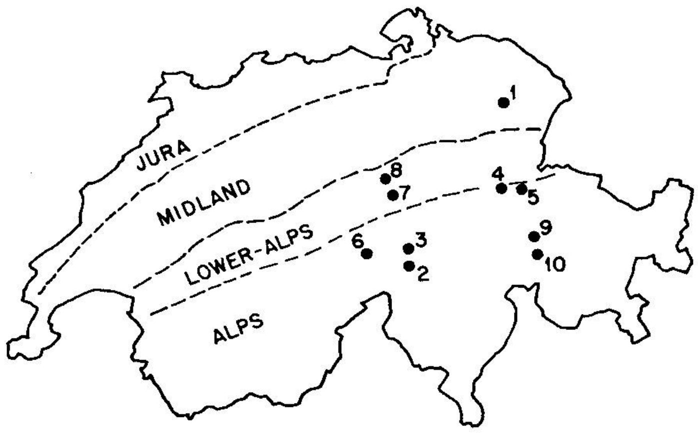
Fig. 18
Main dangers at the Hauenstein-Basistunnel

6. CONCLUSION AND OUTLOOK

Nearly 50% of the total annual accidents occur in the construction industry. As detailed accident statistics are missing, it is imperative to create computer based statistics in the near future, to improve the prevention of accidents. Less accidents in the construction industry are of great interest from the point of view of human health and for economy reasons. The tunnelling world is sure to participate in these efforts.

In the following years more attention has to be paid to the Radon problem in tunnelling works in different zones of the Alps. So far, lasting Radon damages have not been found in workers at Swiss tunnelling sites. Radon protection will nevertheless form an integral part of tunnelling health and safety measures in the near future.

RADON MEASURING STATIONS IN SWITZERLAND



1 POWER PLANT KUBEL
2 GOTTHARD-TUNNEL (SOUTH)
3 GOTTHARD-TUNNEL (NORTH)
4 GALLERY GIGERWALD
5 GALLERY SARELLI
6 GALLERY ROTLAUI
7 SEELISBERG-TUNNEL(SOUTH)
8 SEELISBERG-TUNNEL(NORTH)
9 GALLERY TOMILS
10 GALLERY SCHARANS

Fig. 19
Radon measuring stations in Switzerland

RADON IN ROCK

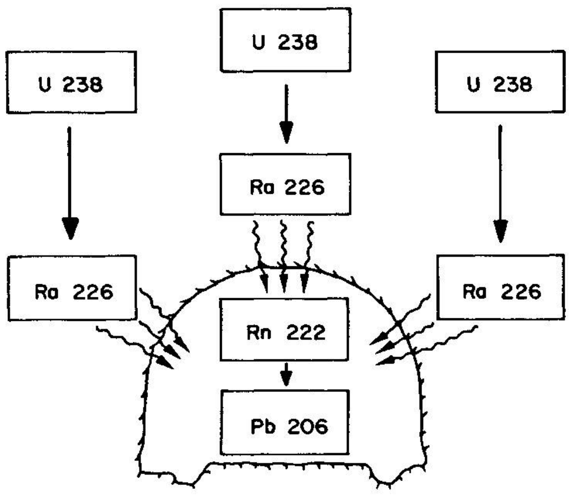


Fig. 20
Radon in rock

Leere Seite
Blank page
Page vide