Part I

Objekttyp: **Group**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **44 (1983)**

PDF erstellt am: **17.05.2024**

Safety Concepts in Japanese Building Industry

Concepts de sécurité dans l'industrie japonaise de la construction

Sicherheits-Konzepte in der japanischen Bauindustrie

Sadamu MINO
Exec. Vice President
Sumitomo Construction Co., Ltd.
Tokyo, Japan

Sadamu Mino, received Bachelor of Engineering from Kyushu University, 1941. Studied Highway Engineering at Ohio State University. In 1966, Director General, Kinki Regional Constr. Bureau. 1970 – 1976 Director and later Chief Engineer, Japan Highway Public Corporation. 1976 joined Sumitomo Constr., Co., Ltd.

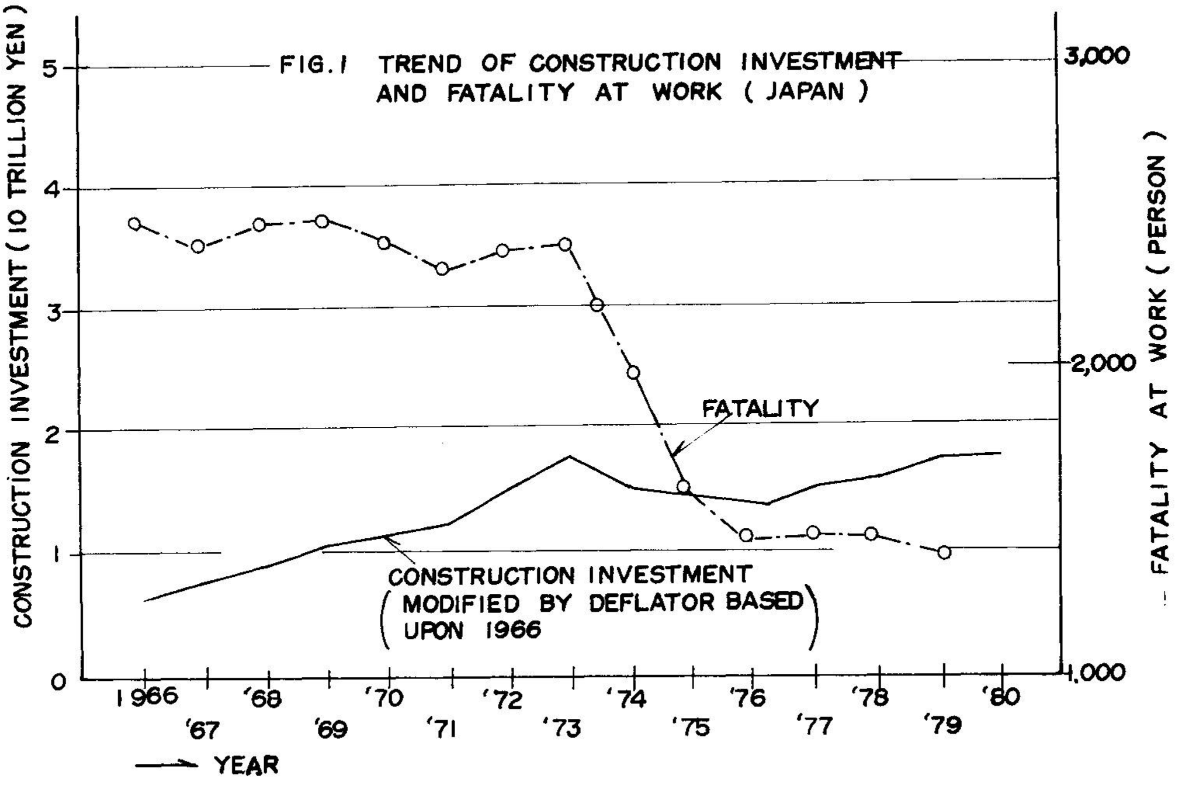
SUMMARY
In spite of steady increase in construction investment, Japan's fatality at construction work has shown remarkable decrease after 1974 – 75. Another visible change is the fact that Japanese construction industry became quite safety-conscious. Administrative measures, the author believes, must have been effective in improving the safety at work.

RESUME
En dépit de l'accroissement constant des investissements dans la construction au Japon, le nombre d'accidents mortels sur les chantiers a diminué de façon remarquable après 1974 – 75. Un autre changement visible est le fait que l'industrie japonaise de la construction a mieux pris conscience de ce problème de la sécurité. L'auteur croit que des mesures administratives ont été efficaces dans l'amélioration de la sécurité sur le lieu de travail.

ZUSAMMENFASSUNG
Trotz ständigem Wachstum der Bauinvestitionen sind in Japan nach 1974 – 75 die tödlichen Unfälle bei Bauarbeiten beträchtlich zurückgegangen. Eine weitere sichtbare Veränderung ist, dass Japans Bauindustrie durchwegs sicherheitsbewusster wurde. Administrative Massnahmen, so denkt der Autor, waren wirkungsvoll bei der Verbesserung der Arbeitssicherheit auf den Baustellen.

1. Today, Japanese construction industry is keenly conscious of safety at work, and 'safety first' is considered as the starting point of all job planning in construction. Even in Japan's construction industry, probably until early 1960s, there had been such thinking as 'accident-norms', which according to Prof. Sikkel, prevails in European construction industry.
How the transition of safety-concepts took place in Japanese construction industry is worth studying.

2. Fig. 1 shows the trend of fatality at work together with construction investment in Japan from 1966-1980. The fatality at work has shown substantial decrease from 2400 in 1973 to 1451 in 1976, and has stayed at this low fatality level since then. Construction investment has shown steady increase during these years, even considering the inflationary factors.



3. There are two probable factors in bringing about the improvement of fatality at work in Japanese construction industry. One is the enactment of "Industrial Safety and Health Law" in 1972. Based on this law, many government ordinances and ministerial ordinances were enacted to ensure the safety at construction work.

4. The other is the disciplinary action taken by the Ministry of Construction against the contractor responsible for accident during construction work.

Japanese Ministry of Construction is in charge of administration over the construction industry, while it is an owner of many public works. It also subsidizes local governments for their public works. Consequently the policies on executing public works determined by MOC are mostly adopted by the public corporations and authorities under the control of MOC as well as local governments.

MOC is the biggest owner of public works in Japan, and executes its works through nine Regional Construction Bureaus and other agencies located all over Japan. Because there are too many projects to be contracted every year, the MOC Agencies omit the prequalification procedure at every project, and instead renew the registration of prospective contractors every other year. At the renewal of registration, contractors have to submit documents indicating their financial capabilities as well as their technical abilities and experiences based upon the latest data. With these materials, the MOC Agencies classify prospective contractors into several grades. When there is a project for bidding, the MOC Agency selects certain number of qualified contractors in the suitable grade among the registered contractors and invites them for competitive bidding. This is the usual practice in the public works projects of MOC.

When an accident happens during construction and is judged to be attributable to the poor management of the contractor on safety, the MOC Agency suspends the qualification of the responsible contractor for certain period according to the rule shown in Annex 1. As seen in the rule, this disciplinary measure is applied to the accidents in works of other owners than that MOC Agency. Other local governments follow the MOC Agencies in taking similar disciplinary actions.

Naturally the contractor in question loses many chances to participate in biddings for that suspended period, and thus may suffer the loss of expected profits. It is very difficult to estimate this kind of economic losses incurred by the temporary disqualification, but generally it is enormous.

5. Because enormous amount of economic losses is incurred by accident during construction work, Japanese building industry is spending substantial expenses for health and safety measures. According to the survey conducted by the Ministry of Labor in 1979, average cost for health and safety measures amount to 2.9 % of the total amount of contract. (Fig. 2) This is quite substantial

amount.

In the light of increasing trend of the costs for health and safety measures, Japanese building industry has requested owners to set up an independent item for the costs for health and safety measures. This request has not yet granted generally, but some company of public utilities created this item answering the request.

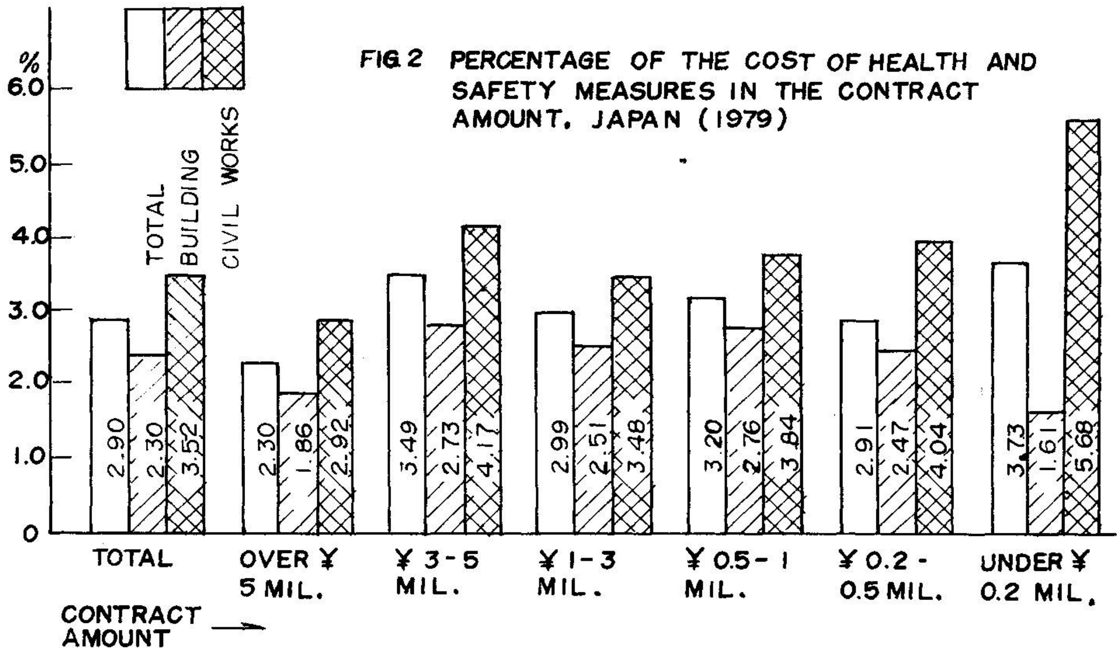


FIG.2 PERCENTAGE OF THE COST OF HEALTH AND SAFETY MEASURES IN THE CONTRACT AMOUNT, JAPAN (1979)

6. The above-mentioned disciplinary action by the Ministry of Construction seems to be very effective as an external force to promote improvement of safety management at work.

Appendix 1

Temporary Disqualification of Registered contractor Responsible for Accident during Construction Work by Regional Construction Bureaus or Other Agencies, Ministry of Construction (hereinafter called 'the MOC Agencies')

enacted on 10th Sept., 1977

1. When a contractor had an accident due to his poor management on safety in the execution of work of the MOC Agency, causing

a. fatality, many injuries or property damage to the public ... 3 - 9 months

b. injury or property damage to the public ... 1 - 6 months

c. fatality or injury to the workers concerned ... 1 - 6 months

2. When a contractor had a very serious accident due to his poor management on safety in the execution of work of other MOC Agency, causing

a. fatality, injury or property damages to the public ... 2 - 5 months

b. fatality or injury to the workers concerned ... 1 - 3 months

3. When a contractor had a serious accident due to his poor management on safety in the execution of work of other owner in the area of the jurisdiction of the MOC Agency, causing

a. fatality, injury or property damage to the public, and

i) the owner was a public agency ... 1 - 3 months
ii) the owner was not a public agency ... 1 month

b. fatality or injury to the workers concerned, and

i) the owner was a public agency ... 1 - 2 months
ii) the owner was not a public agency ... 1 month

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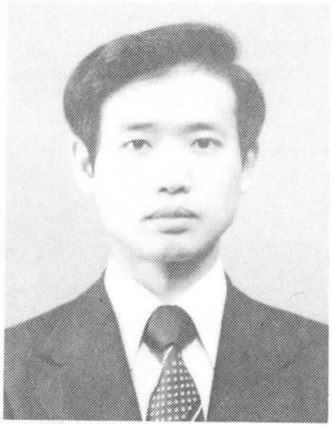
Accidents in the Construction Industry and Preventive Measures

Prévention des accidents dans l'industrie de la construction et règlements de sécurité

Unfälle in der japanischen Bauindustrie und Massnahmen zu ihrer Verhütung

Masato ITO
Electrical Engineer
Safety Div., Minist. Labour,
Tokyo, Japan



Masato Ito, born 1949, got his master of electrical engineering at the University of Gunma. He was a ILO Expert on Skill Developement for two years. Masato Ito is now responsible for the administration on safety of machinery in the Ministry.

SUMMARY
This paper shows the occurrence of accidents in the construction industry. Graphs and tables show the trends of the number, frequency and severity of the workers dead and injured at construction work since 1958. The paper also shows the types of works and injuries as well as measures to prevent accident in the construction industry based on safety regulations and voluntary activities.

RESUME
L'article présente le développement des accidents dans l'industrie de la construction japonaise. Des graphiques et des tabelles montrent l'évolution du nombre de travailleurs décédés et blessés dans l'industrie de la construction depuis 1958, selon le type de travail et le type d'accident. L'article montre des mesures de prévention des accidents dans l'industrie de la construction.

ZUSAMMENFASSUNG
Dieser Bericht zeigt die Entwicklung der Unfallvorkommnisse in der japanischen Bauindustrie. Diagramme und Tabellen zeigen die Anzahl der getöteten und verletzten Arbeiter auf dem Bau seit dem Jahr 1958, nach Arbeitsgattung und Unfallart klassifiziert. Der Bericht zeigt schliesslich Massnahmen zur Unfallverhütung in der Bauindustrie.

1. Introduction

Recently, the occurrence of industrial accidents in the Japanese construction industry has decreased year by year due to the efforts made by parties concerned, but there still are more than 100,000 cases of serious injuries and a little over 1,200 cases of deaths. The rate of accidents is by far higher than in the manufacturing and other industries.

In order to find some way out of the present situation in which such large numbers of industrial accidents take place in the construction industry and give full play to the endeavors to prevent industrial accidents, it is necessary to develop a control system for each business in regard to occupational health and safety and to energetically step up the prevention of labor accidents on a voluntary basis.

Given this situation, the Government is striving to keep the Occupational Safety and Health Law and other laws and ordinances in perfect order for a further thoroughgoint enforcement of measures for the prevention of labor accidents in the construction industry. It is also evolving new comprehensive measures for a further promotion of voluntary labor accident prevention activities on the part of businesses.

2. Present Situation of Labor Accidents in Construction Industry

2.1 Trend in Deaths and Injuries

In Japan, about four million workers are placed on the payroll of the construction industry. Of them, about 240,000 workers suffer from industrial accidents (for which they take one or more days off) each year while they are engaged in construction projects.

Fig. 1 shows fluctuations in the numbers of deaths and injuries requiring four or more rest days in industrial accidents in all industry and the construction industry since 1973. This figure indicates that the number of labor accidents involving deaths and injuries in the construction industry stood at 112,185 in 1958. As it increased year by year, it reached a peak of 137,282. The number of labor accidents involving deaths reached a high of 2,652 in 1961. Presumably, the reason is that the number of workers increased and in this conunction there was a rise in the occurrence of labor accidents as the number of construction projects began to increase all of a sudden in 1959 or so due to a high growth of the Japanese economy. Later, construction projects also increased in number. On the other hand, there was an increased awareness of the necessity of preventing industrial accidents and measures for the prevention of industrial accidents were energetically stepped up, with the result that there appeared signs of a drop in the occurrence of industrial accidents.

Particularly with the enactment of the Occupational Safety and Health Law in 1972 as a turning point, the measures for the prevention of industrial accidents at each establishment were conspicuously replenished and production actively came to a standstill as recession had creeped it. Due partly to such reasons, there has been a sharp drop in the occurrence of labor accidents in the last several years.

In 1981, there were 1,173 industrial accidents involving deaths, down 55.8% from 1961 or 20 years ago. In the same year, however, there were 100,281 industrial accidents resulting in deaths and injuries and requiring more than four rest days, down 27% from 1962. The occurrence of such industrial accidents has leveled off in the last 15 years. The construction industry accounts for 32.1% of the industrial accidents involving deaths in all industry and 40.3% of industrial accidents involving deaths and injuries.

2.2 Trend of Accident Frequency Rate

Fluctuations in the occurrence rates (rate per 1,000 workers a year and frequency rate) and in the severity rate are shown in Figs. 2 and 3. The rate per 1,000 workers a year is about 2.5 times, the frequency rate 1.4 times and the severity rate about 2.4 times as big as in all industry.

2.3 Industrial Accidents in Construction Projects

2.3.1 Industrial Accidents by Type of Construction Work

Of all labor accidents in construction projects, those which require four or more rest days take place to the tune of 100,000 cases a year. Such industrial accidents in 1970, 1975 and 1978 are compared in Table 1 by type of construction work.

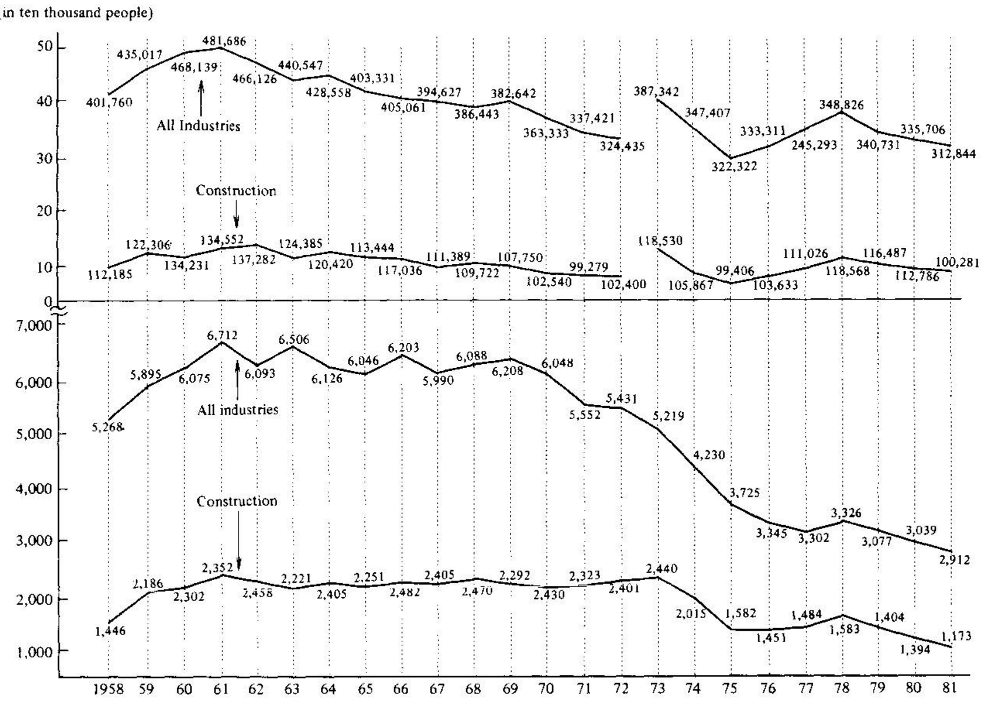
Table 1 indicates fluctuations in the occurrence or industrial accidents by type of construction work. In other words, the number of industrial accidents in construction projects increased by 54% in 1978 but there were corresponding drops in the numbers of civil engineering and facilities construction projects. There was a marked increase in the number of wooden house construction and other civil engineering projects but a drop in that of road construction and machinery installation projects.

Industrial accidents involving only deaths are indicated in Table 2 by type of construction work. In the civil engineering sector, many industrial accidents involving deaths have occurred in road construction, water supply and drainage construction, land readjustment and other projects. In the building construction sector, they have frequently occurred in building (SRC and S) construction and wooden house construction projects. As regards the facilities construction sector, there are many such accidents in telecommunication projects.

2.3.2 Situation of Industrial Accidents by Type

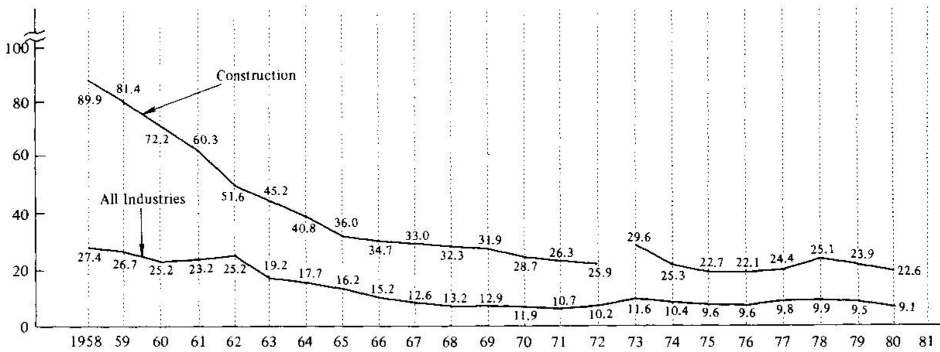
Table 3 indicates the tendency of industrial accidents involving deaths by type of accident. In the construction industry, accidental falls in which workers fall to the ground, etc., while engaging in construction work at high places account for about one-third of all industrial accidents involving deaths. Then there are many accidents in which workers are run over or knocked down by dump trucks, microbuses, trains, etc., or which take place as a result of their spill (accidents by autos, etc.). Quite evident from this table are the facts that there are signs of a rise in the occurrence of accidents by bullodozers, shovels and other heavy machinery and that the number of accidents by landslides, cave-ins, etc., is on the downturn.

Such developments indicate that the number of accidents in which workers are knocked down or run over is on the up-swing as bulldozers, back hoe and other heavy machinery have been adopted



Note: Deaths and injuries requiring 8 days or more for rest (Since 1973, this figure shows the deaths and injuries resting 4 days or more)

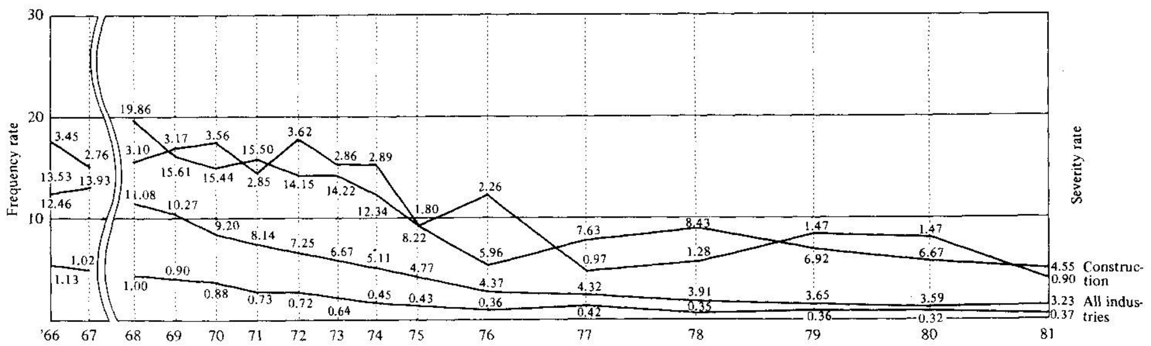
Fig. 1. Trend in Deaths and Injuries



Note: (1) The computation is made on the bssis of the number of persons dead and injured with eight or more rest days for 1972 and earlier years and four or more days for 1972 and later years.

(2) Rate per 1,000 workers a year: Number of persons dead and injured for every 1,000 workers a year.

Fig. 2. Rate per 1,000 Workers a Year



Note: (1) This table refers to the rate of occurrence of death or injury hazards requiring leave of one or more days as investigated by the Statistical Information Department, Japanese Ministry of Labor, Office of the Minister on 15,000 business premises where 100 or more workers are employed for the two calendar years of 1980 and 1981.

Fig. 3. Fluctuations in Frequency and Severity Rates

even at construction sites medium and small in scale due to the progress made in the mechanization of construction work. On the other hand, the number of accidents by landslides, cave-ins, handling, transportation, etc., is on the downswing, as drilling work, handling of heavy equipment and other work which were manually done in the past have been mechanized, thus bringing about a drop in the manual handling of dangerous objects and working in drilled pits.

Incidentally, the occurrence of accidents involving deaths in 1981 is indicated in Table 4 by type of construction work and by type of accident.

2.3.3 Occurrence of Grave Accidents

The accident in which three or more workers suffer is defined as a grave accident by the Ministry of Labor and taken up as the subject of a special investigation and analysis. There have been signs of a drop in the occurrence of grave accidents, but the construction industry accounts for more than half of grave accidents in all industry each year. In the construction industry, it is highly likely that many workers are killed or injured at one time in accidents caused by landslides, cave-ins, collapses, explosions, etc.

The construction industry subjected to this investigation refers to work sites whose individual contract is worth 90 million yen or more, or whose accident insurance premium exceeds 0.6 million yen. However, machine equipment installation, electrical work and piping businesses are not included.

The frequency rate represents the number of labor accident casualties (deaths or injuries) per million working hours; that is a figure obtained by dividing the number of labor accident casualties during the investigation period by the total number of working hours for all the workers who were subjected to the same occupational hazard. The formula is as follows:

$$\text{Frequency rate} = \frac{\text{Deaths or injuries in occupational accidents}}{\text{Total working hours}} \times 1{,}000{,}000$$

The severity rate shows the magnitude of labor accident with lost work days per 1,000 working hours; that is, a figure obtained by dividing the total number of days lost due to occupational accidents by the total working hours of all workers who were subjected to the same occupational hazards during the investigation period. The formula is as follows:

$$\text{Severity rate} = \frac{\text{Lost work days*}}{\text{Total working hours}} \times 1{,}000$$

* Lost work days

(a) Deaths 7,500

(b) Injuries resulting in physical handicaps

Handicap rating	1–3	4	5	6	7	8	9	10	11	12	13	14
Work days lost	7,500	5,500	4,000	3,000	2,200	1,500	1,000	600	400	200	100	50

(c) Injuries causing no physical handicap

$$\text{Work days lost} = \text{leave of days} \times \frac{300}{365}$$

Table 1. Number of Workers Dead and Injured by Type of Construction Work

	Type of Work	1970	1975	1978
		%	%	%
Civil Engineering Construction Work	Dam	474 (0.47)	708 (0.71)	424 (0.36)
	Tunnel	2,146 (2.14)	2,531 (2.55)	1,744 (1.47)
	Subway	573 (0.57)	302 (0.30)	253 (0.21)
	Railroad	1,347 (1.34)	807 (0.81)	1,111 (0.94)
	Bridge	2,134 (2.13)	1,898 (1.91)	1,991 (1.68)
	Road	9,917 (9.89)	10,290 (10.35)	10,830 (9.13)
	River	4,755 (4.74)	5,237 (5.27)	5,258 (4.43)
	Land slide protection	1,975 (1.97)	2,167 (2.18)	2,266 (1.91)
	Land improvement	3,341 (3.33)	3,565 (3.59)	3,819 (3.22)
	Water supply & sewage			
	Harbour	13,113 (13.08)	15,328 (15.42)	17,850 (15.05)
	Others			
	Sub-total	39,775	42,833	45,546
Building Work	Building	22,075 (22.03)	16,849 (16.95)	25,218 (21.27)
	Wooden house	17,992 (17.95)	24,631 (24.78)	29,647 (25.00)
	Pipe arrangement etc.	2,572 (2.57)	2,031 (2.04)	2,693 (2.27)
	Others	5,699 (5.69)	4,689 (4.72)	6,528 (5.51)
	Sub-total	48,338	48,200	64,086
Equipment Work	Electric work	4,547 (4.54)	3,287 (3.31)	3,740 (3.15)
	Machinery	3,576 (3.57)	2,196 (2.20)	1,929 (1.63)
	Others	4,004 (3.99)	2,900 (2.91)	3,267 (2.77)
	Sub-total	12,127	8,373	8,936
Total		100,240 (100.00)	99,406 (100.00)	118,568 (100.00)

Table 2. Occurrence of Industrial Accidents Involving Deaths by Type of Construction Work and by Year

Type of work	Civil Engineering Construction Work													Building Work					Equipment Work					
Year	Dam	Tunnel	Subway	Railroad	Bridge	Road	River	Land Slide Protection	Land Improvement	Water Supply & Sewage	Harbour	Others	Sub-total	Building	Wooden House	Pipe Arrangement etc.	Others	Sub-total	Electric work	Machinery	Others	Sub-total	Unclassifiable	Total
1975	25	67	11	34	49	217	68	45	120	89	47	35	807	278	152	36	17	483	110	78	25	213	79	1,582
(%)	3.1	8.3	1.4	4.2	6.1	26.9	8.4	5.6	14.9	11.0	5.8	4.3	100.0 (53.7)	57.6	31.5	7.5	3.5	100.0 (32.1)	51.6	36.6	11.7	100.0 (14.2)		
1976	14	40	8	22	54	223	60	50	97	105	26	26	725	303	168	36	24	531	91	50	22	163	32	1,451
(%)	1.9	5.5	1.1	3.0	7.5	30.7	8.3	6.9	13.4	14.5	3.6	3.6	100.0 (51.1)	57.1	31.6	6.8	4.5	100.0 (37.4)	55.8	30.7	13.5	100.0 (11.5)		
1977	18	39	8	18	57	203	83	61	74	87	28	33	711	289	147	31	22	489	118	72	22	212	52	1,464
(%)	2.5	5.5	1.1	2.5	8.0	28.6	11.7	8.5	10.4	12.5	3.7	4.7	100.0 (50.4)	59.1	30.1	6.3	4.5	100.0 (34.6)	55.7	33.9	10.4	100.0 (15.0)		
1978	22	44	5	24	80	237	70	55	66	108	56	25	792	286	155	43	16	500	134	54	40	228	63	1,583
(%)	2.8	5.6	0.6	3.1	10.1	29.9	8.8	6.9	8.3	13.6	7.1	3.3	100.0 (50.0)	57.2	31.0	8.6	3.2	100.0 (31.6)	58.8	23.7	17.5	100.0 (14.4)		
1979	16	53	4	21	47	175	39	68	48	101	28	61	661	261	150	31	44	486	103	54	48	205	52	1,404
(%)	2.4	8.0	0.6	3.2	7.1	26.5	5.9	10.3	7.3	15.3	4.2	9.2	100.0 (47.1)	53.7	30.9	6.4	9.0	100.0 (34.6)	50.3	26.3	23.4	100.0 (14.6)	(3.7)	(100.0)
1980	20	36	8	16	48	166	53	42	65	101	42	84	681	273	147	36	20	476	88	45	38	171	46	1,374
(%)	2.9	5.3	1.2	2.3	7.0	24.5	7.8	6.2	9.5	14.8	6.2	12.3	100.0 (49.6)	57.3	30.9	7.6	4.2	100.0 (34.6)	51.5	26.3	22.2	100.0 (12.4)	(3.4)	(100.0)
1981	16	26	6	15	25	166	51	40	62	78	25	57	567	189	129	36	29	383	102	51	40	193	30	1,173
(%)	2.8	4.6	1.1	2.6	4.4	29.3	9.0	7.1	10.9	13.8	4.4	10.0	100.0 (48.3)	49.3	33.7	9.4	7.6	100.0 (32.7)	52.9	26.4	20.7	100.0 (16.5)	(2.5)	(100.0)

Table 3. Deaths by Type (Construction)

Type \ Year		1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Falling		741 (30.0)	738 (29.6)	770 (31.7)	703 (30.3)	675 (28.1)	691 (28.4)	647 (32.1)	487 (30.8)	496 (34.2)	497 (33.9)	495 (31.3)	517 (36.8)	517 (37.5)	425 (36.2)
Flying objects and breakdown		137 (5.5)	141 (5.7)	143 (5.7)	144 (6.2)	103 (4.3)	104 (4.3)	76 (3.8)	104 (6.6)	97 (6.7)	101 (6.9)	130 (8.2)	94 (6.7)	85 (6.2)	91 (7.8)
Cave-in and collapse		243 (9.8)	246 (9.9)	238 (9.8)	246 (10.6)	211 (8.8)	214 (8.8)	162 (8.0)	118 (7.5)	132 (9.1)	101 (6.9)	108 (6.8)	93 (6.6)	93 (6.8)	97 (8.3)
Machinery	Crane etc.	157 (6.4)	107 (4.3)	118 (4.9)	131 (5.6)	133 (5.5)	179 (7.3)	114 (5.7)	72 (5.8)	79 (5.4)	90 (6.2)	116 (7.3)	115 (8.2)	98 (7.1)	77 (6.6)
	Traffic	464 (18.9)	482 (19.3)	436 (17.9)	447 (19.2)	465 (19.4)	393 (16.1)	351 (17.4)	264 (16.7)	230 (15.9)	228 (15.6)	260 (16.4)	222 (15.8)	211 (15.4)	187 (15.9)
	Construction machine etc.	278 (11.3)	308 (12.4)	291 (12.0)	309 (13.5)	314 (13.1)	338 (13.8)	302 (15.0)	274 (17.3)	223 (15.4)	215 (14.7)	233 (14.7)	170 (12.1)	209 (15.2)	161 (13.7)
Electric shock		243 (9.8)	247 (10.0)	209 (8.6)	161 (6.9)	157 (6.5)	155 (6.4)	126 (6.3)	102 (6.4)	77 (5.3)	92 (6.3)	82 (5.2)	70 (5.0)	64 (4.7)	48 (4.1)
Explosion, fire								49 (2.4)	45 (2.8)	47 (3.2)	56 (3.8)	63 (4.0)	37 (2.7)	33 (2.4)	18 (1.5)
Handling etc.		53 (2.1)	18 (0.7)	41 (1.7)	48 (2.1)	48 (2.0)	89 (3.6)	30 (1.5)	33 (2.1)	18 (1.2)	25 (1.7)	29 (1.9)	25 (1.8)	30 (2.2)	10 (0.9)
Others		154 (6.2)	203 (8.1)	184 (7.5)	134 (5.8)	296 (12.3)	277 (11.3)	158 (7.8)	63 (4.0)	52 (3.6)	59 (4.0)	67 (4.2)	61 (4.3)	34 (2.5)	59 (5.0)
Total		2,470	2,492	2,430	2,323	2,402	2,440	2,015	1,582	1,451	1,464	1,583	1,404	1,374	1,173

Note: Explosion, fire is included in "others" until 1973.

Table 4. Deaths by Construction Work

Type of Accidents \ Type of Work		Civil Engineering Construction Work													Building Work					Equipment Work						
		Dam	Tunnel	Subway	Railroad	Bridge	Road	River	Land slide protection	Land improvement	Water supply & sewage	Harbour	Others	Sub-total	Building	Wooden house	Pipe arrangement etc.	Others	Sub-total	Electric work	Machinery	Others	Sub-total	Unclassifiable	Total	Percentage (%)
Falling		6	2	4	1	8	19	4	9	9	9	2	10	83	124	95	21	18	258	33	25	22	80	4	425	36.2
Flying objects and collapse			2	1	1	6	4	7	5	3	4	4	6	43	18	12	1	2	33	9	2		11	4	91	7.8
Land slide and cave-in		1	6				28	4	10	12	23	2	5	91	2				2	2		2	4		97	8.3
Machinery	Crane etc.		2			2	2	8	8	3	5	6	3	39	10	1	2	5	18	5	11	4	20		77	6.6
	Traffic	4	2	1	9	3	54	12	2	14	12	1	14	128	14	12	4	2	32	12	1	5	18	9	187	15.9
	Construction machine	2	9		1	5	51	10	4	19	18	4	11	134	8	4			12	5	3	2	10	5	161	13.7
Electric shock					2						3		1	6	3	1	3	1	8	32	2		34		48	4.1
Explosion, fire			2				2	1						5	2		3		5			1	1	7	18	1.5
Others		3	1		1	1	6	5	2	2	4	6	7	38	8	4	2	1	15	4	7	4	15	1	69	5.9
Total		16	26	6	15	25	166	51	40	62	78	25	57	567	189	129	36	29	383	102	51	40	193	30	1,173	100.0

3. Overview of Legal Control and Measures

There is a need to come to grips with measures for the prevention of industrial accidents in a diversified manner. With this in mind, the Ministry of Labor has combined various systems with one another and systematized measures for the prevention of industrial accidents on the basis of the Occupational Safety and Health Law and its related laws and ordinances.

Table 5. Overview of Measures for Prevention of Industrial Accidents in Construction Industry

- Assurance of safety in planning stage
  - Holding of liaison meetings with order initiators of public works (Ministry of Construction, Ministry on Transport, Ministry of Agriculture, Forestry and Fisheries, Prefectural Governments, Public Corporations, etc.)
  - Preparation of safety programs by contractors
    - Involvement of qualified persons in the formulation of plans
  - Public release of guidelines for safety assessment
  - Examination of plans
    - Screening by the Chief of the Labor Standards Inspection Office
    - Screening by the Minister of Labor
- Establishment of Organizations for Safety and Health
  - Control system for each project site
    - Overall safety and health director
      - Safety supervisor
      - Health supervisor
      - Industrial physicians
    - Safety and health committee
  - Control system for workplaces consisting of various subcontractors
    - General safety and health controller
      - Safety and health controller
        - Chief work officer
      - Master safety and health supervisor
    - Consulative bodies
    - Arrangements for the prevention of industrial accidents at workplaces consisting of various subcontractors
  - Management organization for workers' rescue
    - Installment and maintenance of devices and equipment required for workers' rescue, and master rescue
- Increased safety of construction machinery and facilities
  - Establishment of technical standards
  - Public release of technical quidelines
  - Inspection and examination of particularly dangerous machinery, etc.
- Promotion of safety and health education and limitation of placement
  - Formulation of programs for promotion of safety and health education
  - Safety and Health Education Center
  - Execution of technical lectures and national exams of limitation of placement
  - Execution of education for new workers employed, special education, education for foremen, etc.
  - Execution or training for workers' rescue
  - Trial of the system for Construction Workers' Pocketbooks

Table 5 (Cont'd)

- Encouragement of voluntary activities for the prevention of labor accidents, assistance to small businesses, etc.
  - Activities of the Construction Industry Labor Accident Prevention Association
  - Guidance and assistance to related organizations
  - Activities of the Committee on Safety Measures for Construction of Wooden Houses
  - Loans system for temporary materials of construction work
  - Preparation of rennovation plans and loans system
  - Guidance and assistance in the execution of safety petrols
- Development of research systems
  - Studies at the Research Institute of Industrial Safety (Ministry of Labor)
  - Performance of consignment research

4. Outline of the Industrial Safety and Health Law

Titles of chapters and sub-chapters of the Industrial Safety and Health Law are shown below.

General Provision
- Object
- Responsibilities of Employer

Organization for Safety and Health Management
- General Safety and Health Director
- Safety Supervisor
- Health Supervisor
- Industrial Physician
- Operation Chief
- Safety and Health Committee

Measures for Preventing Hazards and Health Impairment of Workers
- Measures to be taken by Employer

Regulations concerning Machines and Harmful Substances
- Restriction of Transfer
- Examination
- Periodical Voluntary Inspection
- Prohibition of Manufacturing
- Permission for Manufacturing
- Labelling
- Investigation of Toxicity of Chemical Substances

Measures in Placing Workers
- Safety and Health Education
- Limitation of Placement

Industrial Health Preservation
- Working Environment Measurement
- Medical Examination
- Personal Health Record
- Work Prohibition of the Sick

Limitation of Hours of Work
Measures to Keep and Improve Health

License
License
License Examination
Skill Training Course

Safety and Health Improvement Programme
Direction for Preparation of Safety and Health Improvement Programme
Safety and Health Consultation Industrial Safety Consultant
Industrial Health Consultant

Inspection
Notification of Plan
Labor Standards Inspection
Expert Officer for Industrial Safety
Expert Officer for Industrial Hygine
Medical Advisor for Industrial Health
Complaint by Workers
Order of Stopping Use
Report

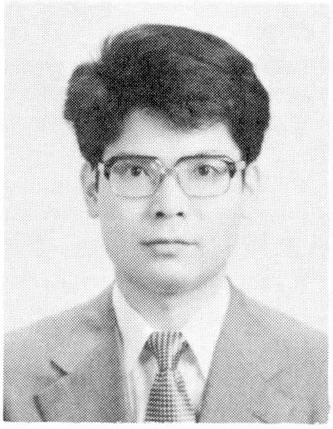
Panalty Rules

Stochastic Analysis of Accidents and of Safety Problems

Analyse stochastique d'accidents et problèmes de sécurité

Stochastische Analyse von Unfällen und Sicherheitsproblemen

Shigeo HANAYSU
Chief Research Engineer
Industrial Safety, Minist. Labour
Tokyo, Japan



Shigeo Hanayasu, born 1945, holds B. Eng. and M. Eng. degrees in Civil Engineering from Hokkaido University, Sapporo, Japan. He is in charge of the Civil Engineering and Construction Research Division in the Industrial Safety Research Institute. For twelve years he is involed in research work on occupational accidents investigation and analysis in construction work.

SUMMARY
The time intervals between occupational accidents can be used as a valuable measurement for evaluating safety performance at working places. The frequency distribution of the occurence of accidents in a fixed time interval is a Poisson distribution, the time intervals between successive accidents are exponentially distributed. Statistically significant accident frequency rates can be used as an early indication of changes in the accident situation.

RESUME
L'intervalle de temps entre les accidents de travail peut être utilisé comme mesure de la sécurité sur les chantiers. La fréquence des accidents est conforme à une distribution de Poisson; les intervalles de temps entre les accidents successifs sont distribués de façon exponentielle. Des taux d'accidents fiables du point de vue statistique peuvent être un indice précurseur du changement de la sécurité sur le chantier.

ZUSAMMENFASSUNG
Die Zeitintervalle zwischen Arbeitsunfällen können zur Messung der Arbeitssicherheit auf Baustellen benützt werden. Die Häufigkeit des Auftretens von Unfällen in einem festen Zeitraum ist Poisson-verteilt, die Zeitintervalle zwischen aufeinanderfolgenden Unfällen sind exponential-verteilt. Statistisch zuverlässige Unfallraten können als frühzeitiger Hinweis auf Veränderungen der Arbeitssicherheit verwendet werden.

1. INTRODUCTION

Every year many occupational accidents take place in the construction industry in Japan. They account for about one third of all occupational accidents, and more than 40% of all fatal accidents. Also, all indices related to occupational accidents in the construction industry, such as the accident frequency rate and the accident severity rate, have higher rates than in many other industries.[1]

The basic reasons why the construction industry is such a dangerous one can be explained from the various point of view. For example, the construction industry has a wide range variety of situations in construction process management, i.e., working conditions as well as environment, and a system of employment of workers, in comparison to that of other industries. These differences might explain the disadvantages concerning occupational accident prevention.[2] Another drawback related to the occupational safety in construction work is that the actual safety management in each construction workplace has to be carried out in accordance with the individual construction site's characteristics. Therefore it is very difficult to formulate a systematic safety management program throughout the construction industry as a whole. Also, the methodology how to evaluate safety performance in working places has not been established, except for the measurement of the accident frequency rate and the accident severity rate.

In this paper, the frequency distribution of the occurrence of occupational accidents was studied from the stochastic point of view, for the purpose of providing a better understanding of the nature of the real accident situation in construction work. Then, based upon the knowledge on the accident situation obtained from observational investigation of the occupational accidents, one fundamental problem in connection with the occupational safety area, the measurement of safety performance in working places, was considered. In particular, emphasis was placed on the stochastic treatment of the time intervals between occupational accidents, regarding it as a useful measurement of safety performance in a working place having a certain accident risk.

In many industrial areas the accident frequency rate has been used as one of the measurement of safety performance over a long period of time. The accident frequency rate is defined as the number of occurrences of occupational accidents for a certain unit of man-power or employee hour exposure. The accident frequency rate, which implies the potential of accident risk in working places, is closely related to the number of occurrences of occupational accidents. This paper, on the contrary, takes the fluctuating time intervals between occupational accidents into consideration instead of the number of occurrence of accidents, in the hope of establishing its usefulness as a measurement of safety performance in working places.

To put it concretely, statistical significant tests for the accident frequency rate using time periods of accidents was considered in order to discover whether there is any significant tendency for changing accident situation in succeeding intervals of time. Also, for the purpose of estimating the unknown exact accident frequency rate, statistival estimation of confidence intervals of the accident frequency rate by means of the time intervals between occupational accidents was proposed.

2. THE BASIC OCCUPATIONAL ACCIDENT SITUATION

To throw light on the basic accident situation in many industrial areas in Japan various types of statistical accident investigation have been conducted by the government every year.[1] According to them, we can, for example, easily find the annual changes of the number of labour accidents, as well as the trends of the accident frequency rate and the accident severity rate in each industry. Also causal agents of accidents and types of accidents are reported as the basic statistics of labour accidents. Obviously, these statistics of accidents will provide a sefety committee or safety experts of a firm with much useful information. However, statistical investigation from the stochastic point of view, such as the frequency distrubution of occurrence of accidents or the time intervals between occuaptional accidents, are not included in the governmental statistical survey program.

Though there is little observatinal investigation concerning stochastic analysis as the time periods between accidents, it is possible to construct the model with the help of the statistics theory. According to the literature of statistics to date, it can be said that if some events are taking place at random and the expectation of the events per unit time is constant, then the frequency distribution of occurrence of events in a fixed interval of time have poisson distribution and the frequency of the time intervals between events are negative-exponentially distributed. It can also be shown that the frequency distribution of the sum of the successive intervals of time of occurrence of events comes to be gamma distribution, provided the time intervals between events is exponentially distributed. [3]

In order to clarify if the actual accident situations agree with the poisson process mentioned above, several observational investigations on the frequency distribution of occurrence of occupational accidents in various types of population was conducted.[4,5] Fig.-1 shows the frequency distribution of the number of occurrences of fatal accidents (deaths) in one day in the Tokyo metropolitan area in the year of 1973, classified by industry. From this figure it could be recognized that each industry has its frequency distribution in accordance with the poisson distribution. (Tests of goodness of fit were applied to verify if the observed distributions agree with the supposed poisson distribution and no significant difference was found between these distributions.) Also several frequency distributions of the number of fatal accidents in one day in various kinds construction sectors such as wooden-house construction, building construction, tunnel construction, bridge construction and road construction, in the year of 1977 are illustrated in Fig.-2 respectively. Clearly the frequency distribution in each construction sector had distributed as poisson distribution similar to Fig.-1. Hence, as far as the fatal accidents are concerned, we can conclude that they might take place at random in various work situations.

For the sake of getting further information on accident situations, especially individual construction site, another investigation on the frequency distribution

$$P(x)=\frac{m^x e^{-m}}{x!}$$

	Construction	Others	All Ind.
m	0.493	0.447	0.940

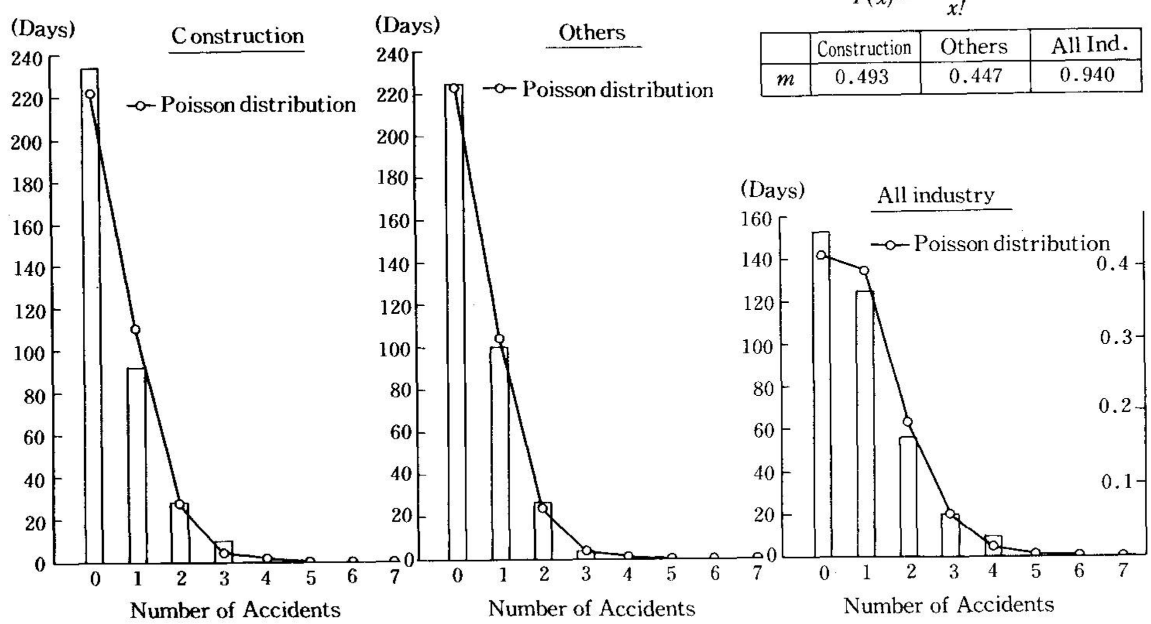
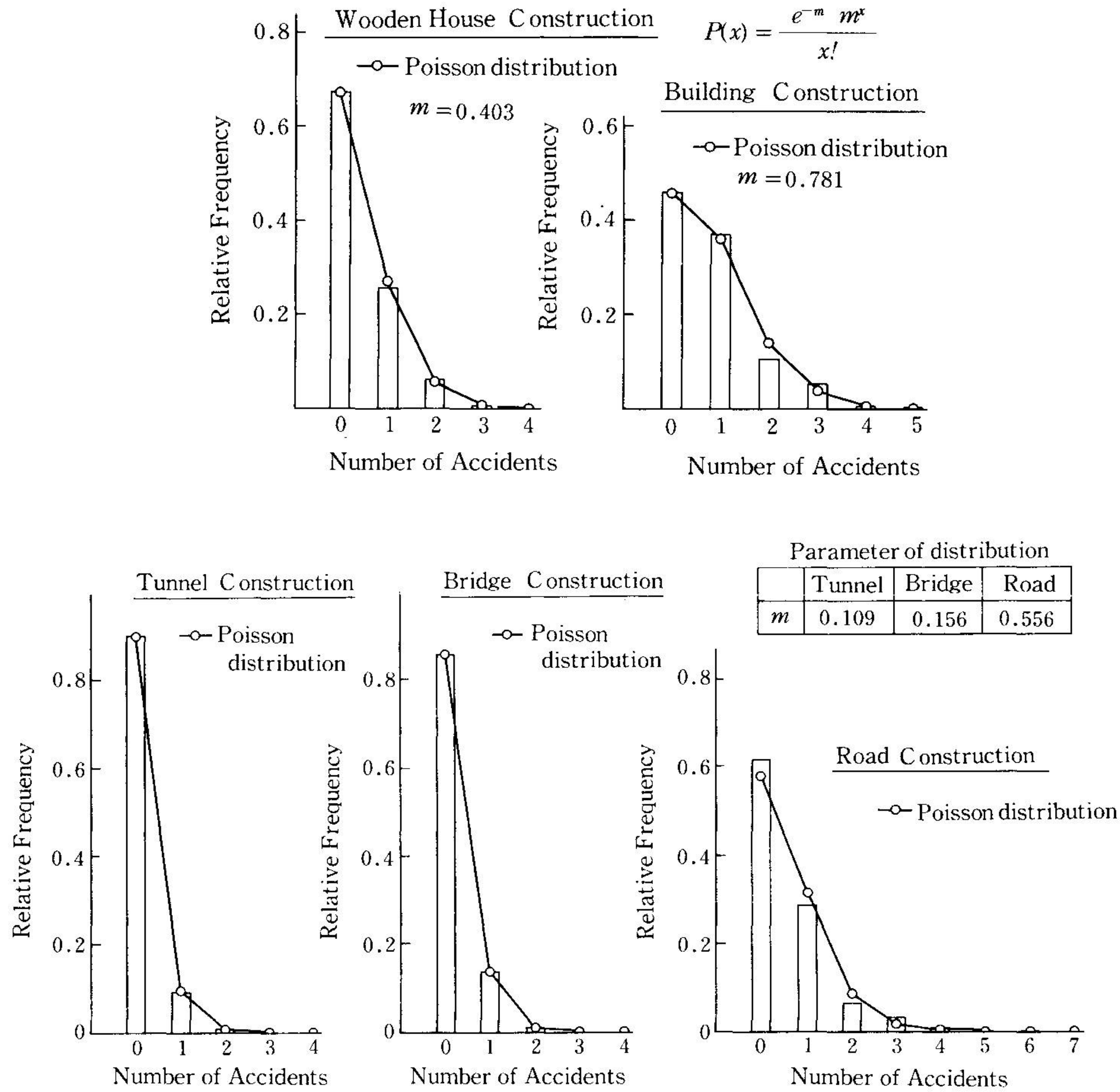


Fig.-1 Frequency Distributions of Fatal Accidents in Tokyo in the Year of 1973, classified by Industry



	Tunnel	Bridge	Road
m	0.109	0.156	0.556

Fig.-2 Frequency Distributions of Fatal Accidents in various Construction Sectors in the Year of 1977

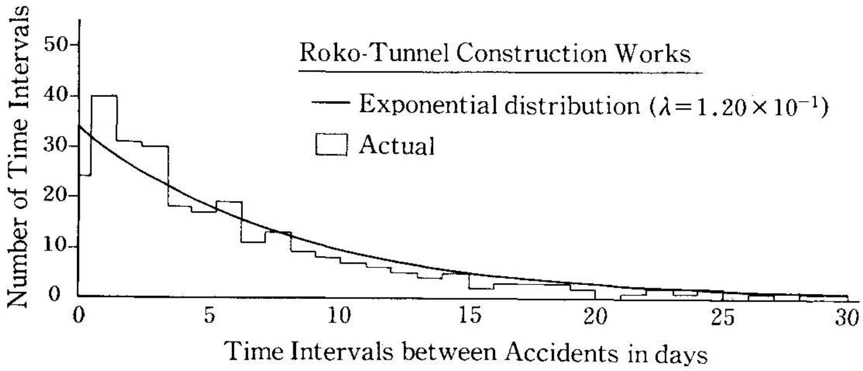


Fig.-3 Time Intervals between successive Accidents in days in a Tunnel Construction Site of the time intervals (in days) between all injury accidents in a tunnel construction site (Rokko tunnel in the New Sanyo rapid trunk line), was performed as shown in Fig.-3. Besides fatal accidents as in Fig.-1 and 2, all injury occupational accidents in this construction site showed up approximately at random, that is the time intervals between successive accidents becomes a rough exponential distribution as exhibited in Fig.-3. In this connection, another example can be seen in the work by B. A. Maguire, et al., in which the time intervals between successive compensable accidents in one district of a British mine was approximately distributed as the exponential distribution.[6] Therefore, depending upon these statistical evidences concerning accident situations obtained through several accident investigations, it may be possible to assume that occupational accidents take place at random, so that the number of occurrences of accidents have the poisson distribution and the time intervals between successive accidents becomes the exponential distribution, to at least a rough approximation. In short, exponential/gamma distribution can be used as the frequency distribution of the time intervals between occupational accidents in the following discussion. The probability density functions of the exponential and gamma distribution are expressed as in the following equations.

$$f_1(t) = \lambda e^{-\lambda t} \quad \text{-----------------(1)}$$

$$E_1(t) = 1/\lambda \quad , \quad V_1(t) = 1/\lambda^2$$

$$f_K(T) = \frac{(\lambda T)^{k-1}}{(k-1)!} \lambda e^{-\lambda T} \quad \text{-----------------(2)}$$

$$E_K(T) = k/\lambda \quad , \quad V_K(T) = k/\lambda^2$$

where : k is the number of occurrence of accidents
T is the sum of k intervals of time between successive accidents
E(·) is the expectation, V(·) is the variance of the distribution

3. EVALUATION OF SAFETY PERFORMANCE IN WORKING PLACES USING TIME INTERVALS [7]

Since the probability density functions of the time intervals between occupatioal accidents are expressed as exponential or gamma distribution shown above, statistical evaluation for safety performance in workplaces using time intervals between occupational accidents can be conducted by executing integration of these density functions.

In order to calculate a probability of the exponential/gamma distribution, it is necessary to estimate a value of λ, a parameter of these distribution functions , prior to the calculation. As a statistical property of exponential distribution, the parameter λ agrees with the reciprocal number (inverse) of the expectation of the distribution. Meanwhile, the accident frequency rate is defined (in Japan) as the number of occurrence of accidents per 1,000,000 man-hour exposure, so that the mean time between accidents could be calculated as 100/A. (unit is 10,000 hour) Therefore, the parameter λ of the exponential as well as gamma distribution can be connected to the accident frequency rate as in the following manner;

$$\lambda = A/100 \quad \text{----------------------(3)}$$

where : A is an accident frequency rate in work places

Then the probability whether an accident will occur or not within a given time t for a certain accident frequency rate can be calculated by equation(4) and (5) respectively.

$$F_1(t) = 1 - \exp\{-At/100\} \quad \text{---------------(4)}$$

$$R_1(t) = \exp\{-At/100\} \quad \text{------------------(5)}$$

Also the probability whether k occupational accidents will take place or not within a particular time T for a certain accident frequency rate can be analyzed by the gamma distribution similar to exponential distribution.

$$F_K(t) = 1-\sum \frac{(AT/100)^i}{i!} \exp\{-AT/100\} \quad \text{-------}(6)$$

$$R_K(T) = \sum \frac{(AT/100)^i}{i!} \exp\{-AT/100\} \quad \text{----------}(7)$$

Fig.-4 shows an illustrated example of the probability density function of the gamma distribution given by equation(2), assuming that the accident frequency rate equals to 20.0. Also, an example of the upper probability distribution function given by equation(7) is illustrated in Fig.-5, in the case of the number of

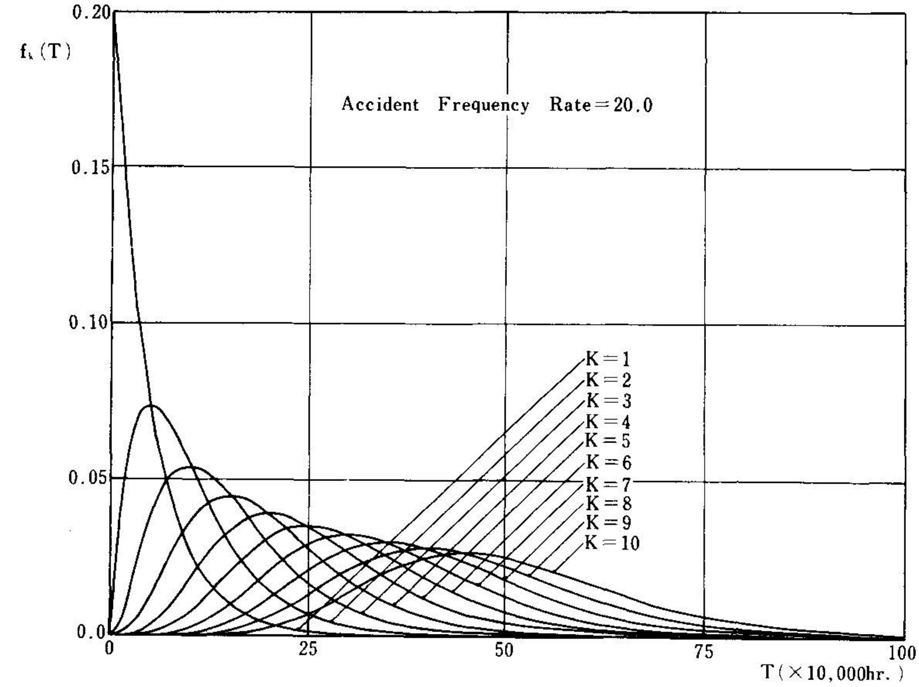


Fig.-4 Probability Density Function of Gamma Distribution

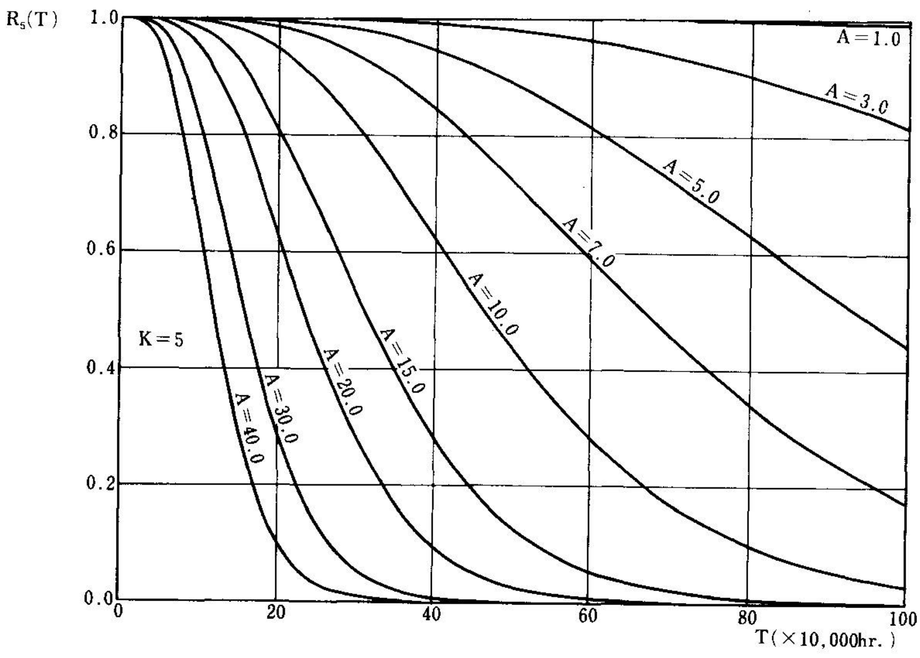


Fig.-5 Probability Distribution Function of Gamma Distribution

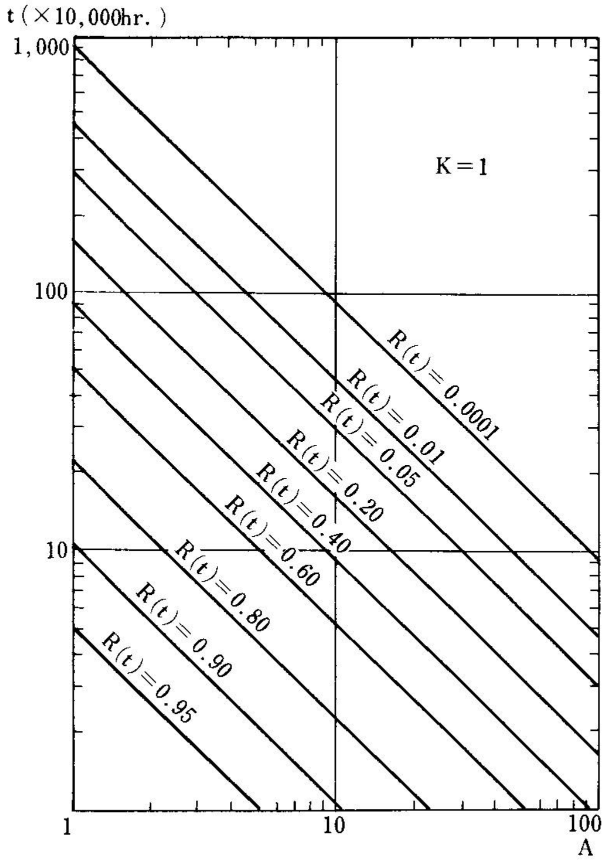


Fig.-6 Relation between $R_1(t)$, t and Accident Frequency Rate

accidents k=5 corresponding to various accident frequency rates. As shown in this figure, the relation between the time interval of accidents and the probability of its occurrence is explained by the distribution function for each combination of the accident frequency rate and the number of accidents.

Hence, for the purpose of measuring safety performance in working places, statistical evaluation of the time intervals between occupational accidents can be easily achieved by making use of these distribution functions. Namely, since equation(5) gives the probability that an accident will take place after the time period of t, the corresponding equation could be used for evaluating a time interval in which no accident has happened. Thus this equation is useful for planning a target of non-occurrence time period in which a safety committee of a firm attempts to avoid any accident from taking place (the so-called zero-accident campaign). In Fig.-6 the relation between $R_1(t)$ given by equation (5), time intervals between accidents and the accident frequency rate are illustrated. With the help of this material, setting a goal of non-occurrence period could be performed in accordance with the accident frequency rate in the working place. For example, a safety committee in an operating work place having an accident frequency rate 10.0, is thinking of promoting a zero-accident campaign and intends to set up a non-occurrence time period. The question is how many working hours should be set up as the goal of non-occurrence period. When we set up 46.1 (×10,000) hour as the goal of time period, no accident will take place within the same period with the probability of 1%, 30.0 hour with the probability of 5 %, and so on. The amount of the probability that must be chosen in the process of setting the goal period, is a problem that depends upon the attitude of the manager or the safety committee in the firm.

Also, as another example, statistical significance tests for the accident frequency rate can be applied to discover whether there is any significant tendency for changing accident risk situation in succeeding intervals of time, by making use of these distribution functions. This is described as an application of a test of hypothesis to the accident frequency rate by use of the time intervals between occupational accidents. The procedure for the tests of hypotheses to the accident frequency rate is depicted as below;

1) present a null hypothesis of the accident frequency rate
   $H_0 : A = A_0$ (A_0 : initial accident frequency rate)

2) specify an alternative hypothesis of accident frequency rate such as;
   a) $H_1 : A = A_1 > A_0$ (one-sided alternative)
   b) $H_1 : A = A_1 < A_0$ (one-sided alternative)
   c) $H_1 : A = A_1 \neq A_0$ (two-sided alternative)

Here, let's take Case "a" first, as an alternative hypothesis against the null hypothesis, which is considering a worse case in an accident risk situation. This test is asking if the accident frequency rate is getting larger in comparison to the initial rate. Then,

3) compute a critical time period $T\alpha_1$, at a significant level α. Equation(6) gives the time of $T\alpha_1$ as follows;

$$\sum \frac{(A_0 T\alpha_1/100)^i}{i!} \exp\{-A_0 T\alpha_1/100\} = 1-\alpha \quad \text{--------}(8)$$

4) make a decision by comparing $T\alpha_1$ with an actual time of the sum of k successive intervals T_K. If the actual time T_K is smaller than $T\alpha_1$, say $T_K < T\alpha_1$, then we can reject the null hypothesis and conclude that the accident frequency rate at the time T_K may have a higher rate than the initial one, so that the accident situation is becoming worse. Fig.-7 demonstrates the relationship between A_0 and $T\alpha_1$, corresponding to the number of accidents, assuming the significant level is α= 5%. Accordingly, this diagram can be employed with reference to this testing hypothesis to the accident frequency rate. Namely, if the actual time T_K is below (inside) the critical time represented by each line in this figure, then we can draw the conclusion mentioned above.

On the other hand, suppose Case "b", as another alternative hypothesis against the null hypothesis which, in this case, is considering a better condition of the accident situation. This test is asking if the accident frequency rate is becoming smaller rate compared with the initial rate. Then,

3') critical region of time $T\alpha_2$, in this case, satisfies the equation(7) as;

$$\sum \frac{(A_0 T\alpha_2/100)^i}{i!} \exp\{-A_0 T\alpha_2/100\} = \alpha \quad \text{-----------}(9)$$

4') comparison $T\alpha_2$ with an actual time T_K yields the decision. If the actual time of the sum of the k successive intervals T_K is longer than $T\alpha_2$, say $T_K > T\alpha_2$, then we can reject the null hypothesis and conclude that the accident frequency rate changes into a smaller rate than the initial one. Consequently the accident situation has been improved. Fig.-8 illustrates the relation between $T\alpha_2$ and A_0,

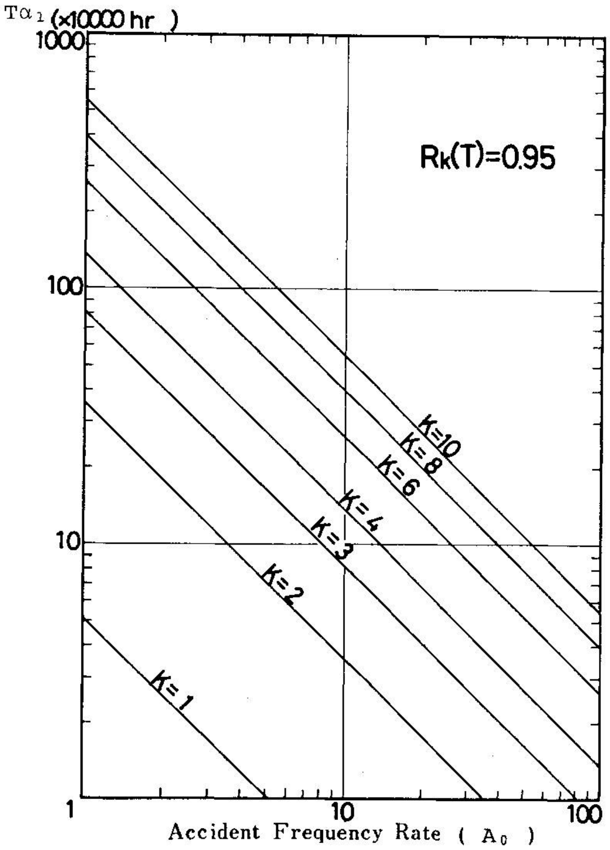


Fig.-7 Relation between A_0 and $T\alpha_1$ ($A_0 < A_1$)

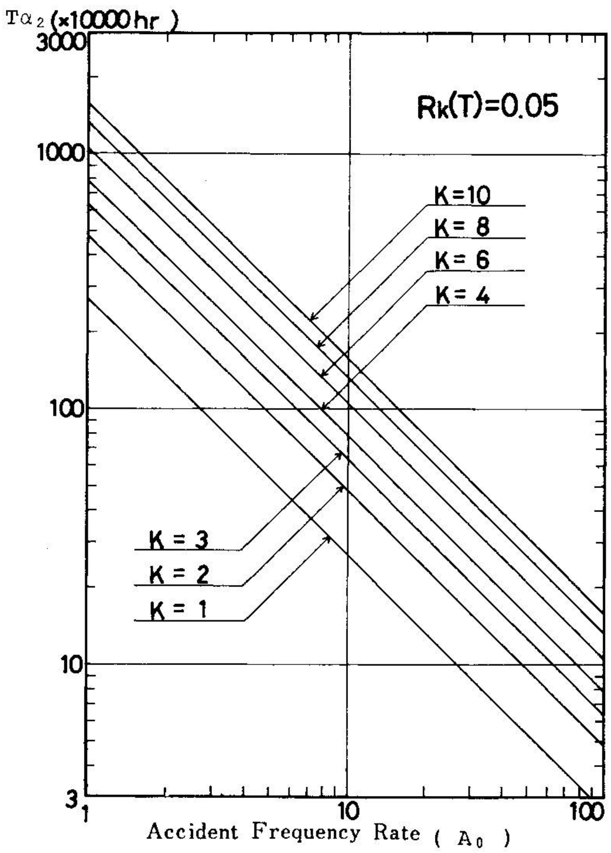


Fig.-8 Relation between A_0 and $T\alpha_2$ ($A_0 > A_1$)

Table-1 Accident Frequency Rates and Severity Rates in Construction Sectors

Industry \ Classification	1979 Frequency		1979 Severity rate	1980 Frequency		1980 Severity rate
	Casualties	Deaths		Casualties	Deaths	
All industries	3.65	0.02	0.36	3.59	0.02	0.32
Construction (general)	6.92	0.13	1.47	6.67	0.08	1.47
Civil engineering	8.20	0.30	2.79	8.75	0.10	2.79
River engineering	12.43	0.12	5.12	9.48	–	1.52
Railway construction	10.71	–	0.39	5.66	–	7.16
Bridge construction	4.79	0.09	1.06	5.53	0.05	0.59
Tunnel construction	19.72	0.99	8.45	15.90	0.22	1.61
Hydro station etc. new construction	6.58	0.26	2.30	7.06	0.35	3.06
Subways new construction	5.21	0.22	1.81	8.62	0.29	2.63
Roads new construction	4.36	0.20	1.72	5.10	–	0.50
Other construction	5.25	0.13	1.09	7.66	0.05	0.60
Building works	6.09	0.02	0.60	5.87	0.07	0.79
Other building	10.99	0.04	0.55	9.70	0.13	1.22
Machinery installation	1.11	–	0.07	2.37	0.08	0.68
Electrical works	2.87	0.06	0.50	2.91	0.10	0.85
Piping (excluding well excavations)	6.51	–	0.14	5.79	0.04	0.45

corresponding to the number of accidents at the significant level α=5%. Similar to the previous instance, relying upon this figure, we can reach the above conclusion if the actual time T_K exceeds (outside) the critical time region represented by each line in this figure.

Table-1 shows the accident frequency rates and the accident severity rates in various construction sectors in Japan for the year 1979 and 1980. This table will be useful for estimating an initial accident frequency rate A_0 in conducting the test of hypothesis to the accident frequency rate.

4. INTERVAL ESTIMATION OF ACCIDENT FREQUENCY RATE USING TIME INTERVALS [7]

Another important reserach area in connection with the use of the time intervals between occuaptional accidents is to estimate the unknown exact accident frequency rate from a stochastic point of view.

Suppose the situation in an operating work place where k labour accidents have taken place at the time T (×10,000) hour (this implies k-1 accidents have already happened before T in advance), then the accident frequency rate is calculated as A = k/T×100 as usual. This sampled (in a statistical meaning) accident frequency rate analyzed in this way from the observed accident data should be regarded as a point estimate of the unknown exact value of the accident frequency rate from the statistical viewpoint. In fact, it can be shown that this sampled accident frequency rate calculated from the observed accident data, agrees with the maximum likelihood solusion derived from the exponential distribution. This sampling accident rate depends on the probability law as below;

If the time intervals between occupational accidents t, is distributed as frequently used exponential distribution expressed in equation(1), then a transformed random variable χ^2 (=2λt=At/50) gives rise to a χ^2 distribution function having the degree of freedom ϕ = 2 as expressed in equation(10).

$$f(\chi^2) = \frac{1}{2}\exp\{-\chi^2/2\} \qquad \text{-----------------(10)}$$

Then the probability that the real unknown exact accident frequency rate exists in a range of A_1 and A_2 ($A_1 < A_2$) when an accident has occurred at a certain time t, can be calculated as in the following manner;

Suppose the variables as $\chi_1^2 = 2\lambda_1 t$, $\chi_2^2 = 2\lambda_2 t$ and keep t constant, then

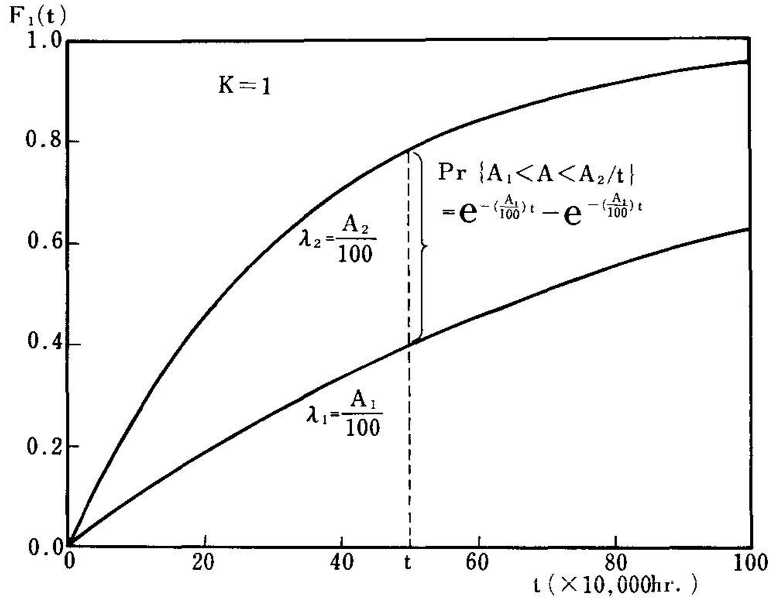


Fig.-9 Notional Sketch of the Probability of the Real Accident Rate in A_1 and A_2

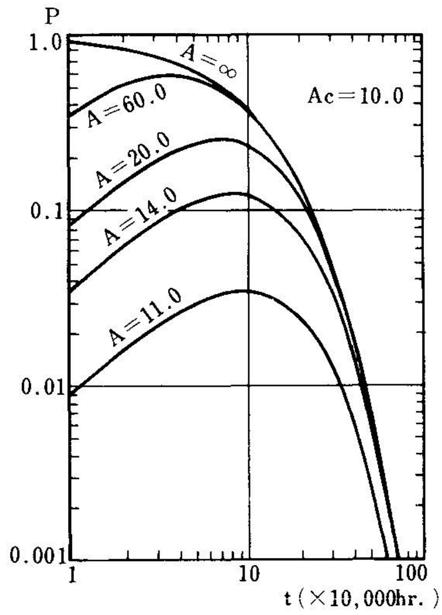


Fig.-11 Probability of Frequency Rate greater than Ac

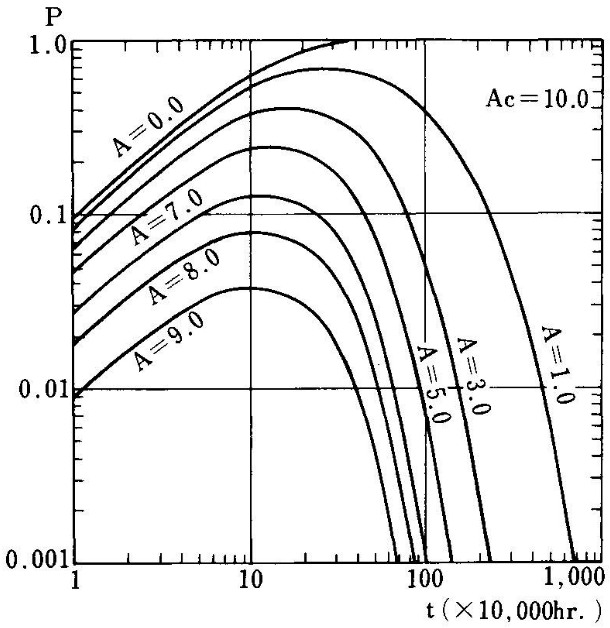


Fig.-10 Probability of the Frequency Rate less than Ac

$$
\begin{aligned}
&\Pr.(\ \chi_1^2 < \chi^2 < \chi_2^2\ ) \\
&= \Pr.(\ 2\lambda_1 t < 2\lambda t < 2\lambda_2 t\ ) \\
&= \Pr.(\ A_1 < A < A_2 \mid t\ ) \\
&= \exp\{-A_1 t/100\} - \exp\{-A_2 t/100\}
\end{aligned}
\qquad \text{------(11)}
$$

This mathematical deduction is shown in the sketch of Fig.-9 graphically, in which the probability of the real accident frequency rate stands between an interval of the accident frequency rate A_1 and A_2, is shown as the difference of two distribution functions of exponential distribution including the parameter of A_1 and A_2.

Also, suppose the situation in a work place where a number of k accidents have taken place at a particular time T, then the existing probability of the unknown exact accident frequency rate in a range of A_1 and A_2, can be analyzed through the transformation of the variables of gamma distribution similar to exponential distribution. This interval probability is derived in the same fashion as the exponential distribution. Namely, as shown in equation(12), the difference between two distribution functions of gamma distribution yields the probability discussing here.

$$
\Pr.(\ A_1 < A < A_2 \mid T\ ) = \sum \frac{(A_1T/100)^i}{i!} \exp\{-A_1T/100\} - \sum \frac{(A_2T/100)^i}{i!} \exp\{-A_2T/100\} \qquad \text{------------------(12)}
$$

Fig.-10 shows several examples of the probability that the unknown real accident frequency rate stands between Ac and other different frequency rates less than Ac. In the case of A = 0.0 in this figure, which representing the probability $\Pr.(0.0 < A < Ac)$, is equal to the probability less than Ac. Also Fig.-11 illustrates several examples of the probability of the real accident frequency rate exists between Ac and other rates greater than Ac. In this figure, the case of A = ∞, indicating Pr.(Ac < A < ∞) is the probability greater than Ac. From the consideration above, it can be said that the evaluation of any arbitrary interval of accident frequency rate in reference to a probability, can be performed by making use of equation(11) and (12).

On the other hand, the so called statistical interval estimation (for accident frequency rate) is depicted in the reverse way of thinking as discussed above. That is, define the probability α first, which is quoted as a level of significance. Then estimate an interval of accident frequency rate in which the exact real accident frequency rate exists with the probability 1-α. To do this a sampling χ^2 distribution is used.

Let's consider the simple case k=1 first. As previously mentioned, the time intervals between occupational accidents t, can be transformed to a χ^2 ($=2\lambda t = At/50$) random variable which depends on the χ^2 distribution with the degree of freedom $\phi = 2$. Thus from an existing χ^2 table we can easily find both the upper $\chi^2_{\alpha/2}$ and the lower $\chi^2_{1-\alpha/2}$ points which satisfy the χ^2 distribution function as;

$$Pr.(\chi^2_{1-\alpha/2} < \chi^2 < \chi^2_{\alpha/2}) = 1-\alpha$$

Then the confidence interval for the unknown exact accident frequency rate corresponding to a certain significant level α could be obtained as in equation(13).

$$(A_{LL}, A_{UL}) = \left[\frac{50\chi^2(2;1-\alpha/2)}{t}, \frac{50\chi^2(2;\alpha/2)}{t}\right] \quad \text{------(13)}$$

where : $\chi^2(\phi;\alpha)$ is χ^2 point with upper probability α, degree of freedom φ

Fig.-12 exhibits the confidence intervals for the accident frequency rate at the significant level α = 1, 5 and 10 % respectively. From the figure, for example, if an accident takes place at 10 (×10,000) hour, then we can estimate the confidence interval as 0.5 < A < 30.0 with the level of significance α = 10%.

Meanwhile, let's consider the distribution of the mean time interval between

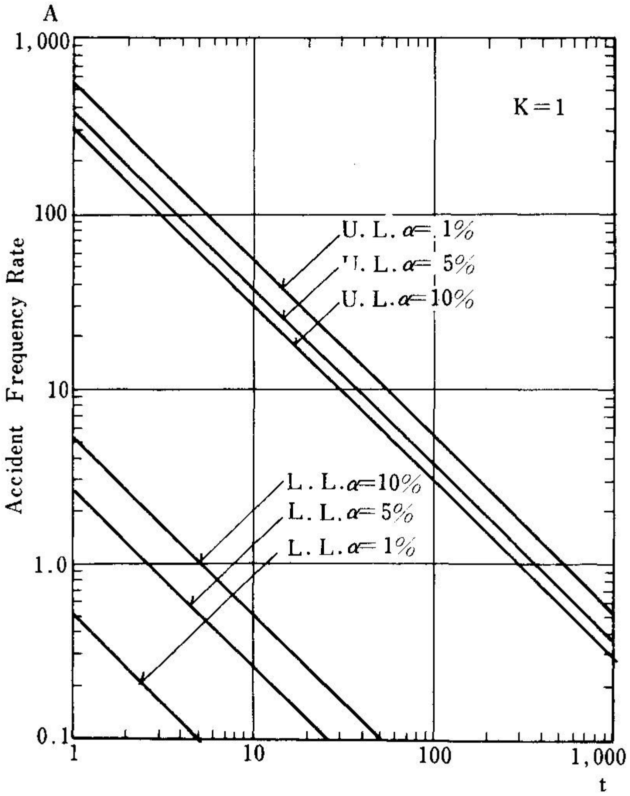


Fig.-12 Interval Estimation of Accident Frequency Rate (k=1)

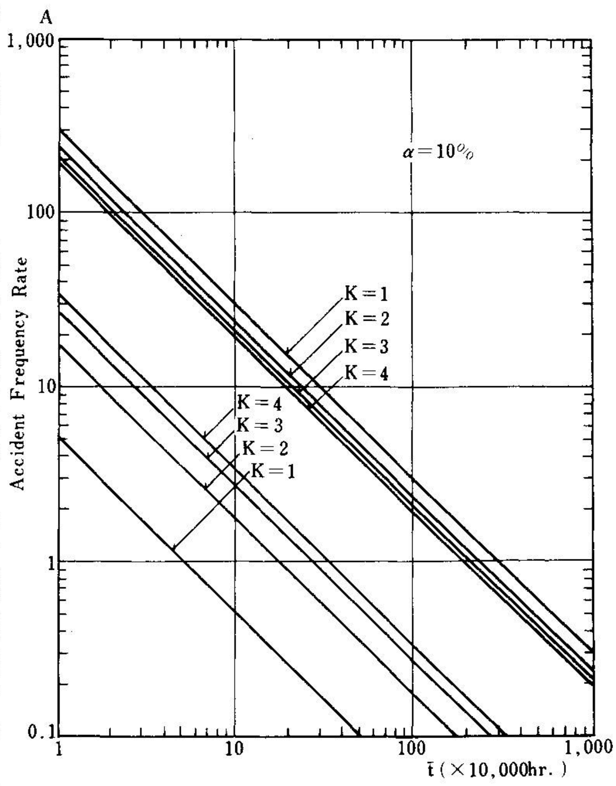


Fig.-13 Interval Estimation of Accident Frequency Rate (α =10%)

occupational accidents $\bar{t}$ here, in order to implement the estimating of the confidence intervals of the accident frequency rate for the case of a number of accidents. It is well known that the distribution of the mean of k successive intervals becomes Erlang distribution as written in equation(14), provided the time intervals between accidents is exponentially distributed.

$$f_K(\bar{t}) = \frac{(k\lambda)^k}{(k-1)!}\bar{t}^{(k-1)}\exp\{-k\lambda\bar{t}\} \quad \text{---------(14)}$$

$$E_K(\bar{t}) = 1/\lambda \quad , \quad V_K(\bar{t}) = 1/k\lambda^2$$

Now it can be followed from Erlang distribution that a transformed random variable $\chi^2(=2k\lambda\bar{t}=Ak\bar{t}/50)$ becomes χ^2 distribution with the degree of freedom $\phi=2k$ as shown in equation(15).

$$f_K(\chi^2) = \frac{(\chi^2/2)^{2k/2-1}}{2(k-1)!}\exp\{-\chi^2/2\} \quad \text{---------(15)}$$

Then a χ^2 probability table can be employed in the analysis for estimating the confidence intervals of the unknown exact accident frequency rate. Through the same procedure as of k=1, we can get the confidence intervals for the accident frequency rate in the case of a number of k accidents as ;

$$(A_{LL}, A_{UL}) = \left(\frac{50\chi^2(2k;1-\alpha/2)}{k\bar{t}}, \frac{50\chi^2(2k;\alpha/2)}{k\bar{t}}\right) \quad \text{---(16)}$$

Fig.-13 illustrates the confidence intervals of the accident frequency rate assuming the significant level α = 10 %. As shown in this figure, the more the accidents occur, the narrower the width of the confidence intervals of the accident frequency rate becomes,owing to the increment of the information about the accident situation in work places.

5. SUMMARY AND CONCLUSION

From the study mentioned above, it can be summarized and concluded as follows:

1) If the occuaptional accidents are taking place at random, then the frequency distribution of occurrence of accidents in a fixed interval of time have the poisson distribution and the time intervals between successive accidents becomes the exponential distribution. From several observational investigations of accidents in various construction sectors, it was recognized that the frequency distribution of fatal accidents had become as poisson distribution and all injury accidents on a certain tunnel construction site had an approximate exponential distribution. Consequently, exponential/gamma distribution, to at least a rough approximation, can be used for the analysis of evaluating safety performance.

2) Accident frequency rate that indicates the accident risk potential, can be connected to the parameter of the exponential and gamma distribution. Then the probability whether some accidents will occur or not within a particular time for a certain accident frequency rate can be calculated by the probability distribution functions.

3) Statistical significant tests to the accident frequency rate , as a typical application of test of hypothesis, can be achieved by making use of the time periods between accidents, to explore whether there are any significant changes in the accident situation in succeeding intervals of time.

4) Transformation of exponential and gamma distribution into χ^2 sampling distribution make it possible to evaluate the probability that the unknown real accident frequency rate exists within an arbitrary interval of accident frequency rate. Also, the statistical estimation of the confidence intervals of the accident frequency rate was proposed by means of stochastic treatment of the time intervals between occupational accidents.

In conclusion, it is apparent that the time intervals between occupational accidents can be used as a valuable measurement for evaluating safety performance in working places. It can be used especially as an early indication of significant changes in the accident situation by means of the statistical significant tests to the accident frequency rate. Also interval estimation of the accident frequency rate using time periods between accidents will provide a safety committee with much useful information in order to implement various types of safety programs.

Finally the author wishes to express his appreciation to those government officials who had given assistance in conducting the accident investigations.

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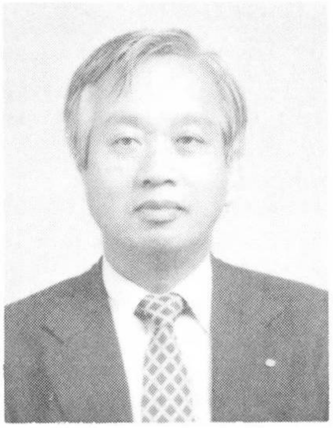
Accident Prevention by Mechanization of Works

Prévention des accidents par. la mécanisation du travail

Unfallverhütung durch Mechanisierung der Arbeiten

Shoji MIYAZAKI
Executive Director
Kawada Industries, Inc.
Tokyo, Japan



Shoji Miyazaki, born 1927, got his civil engineering degree at the University of Tokyo. For thirty years he worked as civil servant in the Ministry of Construction and Tokyo Expressway Public Corporation including three years dispatched to Japanese Embassy in Manila. Shoji Miyazaki, now is a fabricator of steel structures, is in charge of bridge department. Concurrently, he is a member of the Bridge Committee of Japan Road Association.

SUMMARY
The safety of workers in construcion is one of the most serious problems posed to those who are in charge of the management of any site of construction works. In order to realize the objective, the safety measures and facilities should be incorporated in the structure itself. It is important to analize the causes of accidents, to find out where dangers for workers exist, and try systematically to keep workers out of hazardous places.

RESUME
La sécurité des ouvriers est un des problèmes les plus importants posés au responsable de l'organisation de tout chantier de génie civil. Afin d'atteindre leurs buts, les mesures et systèmes de sécurité devraient être incorporés à la structure elle-même. Il est important d'étudier les causes des accidents, de localiser les dangers potentiels pour les ouvriers et d'éviter, de façon systématique, les emplacements dangereux pour les ouvriers.

ZUSAMMENFASSUNG
Die Sicherheit der Bauarbeiter ist eines der bedeutendsten Probleme für alle diejenige, die für die Bauausführung verantwortlich sind. Um das Ziel zu erreichen, sollten die Sicherheitsmassnahmen und -systeme bereits beim Entwurf des Tragwerks berücksichtigt werden. Es ist wichtig, die Unfallursachen zu analysieren, die für die Arbeiter bestehenden Unfallgefahren herauszufinden und die Arbeiter systematisch von gefährlichen Stellen fernzuhalten.

According to recent statistics of accidents occured in the construction industry of Japan, the leading cause of fatal accidents was falls of workers from elevation, amounting to 37% of the total, and 6% of fatal accidents were caused by falling objects striking unfortunate workers. In total, 43% of fatal accidents during construction period took place because the labourers were positioned in such dangerous places that if some unanticipated happenings occured they would entail accidents to death to the labourers. In other words, if we succeed in keeping the workers out of dangerous places we will be able to eliminate almost half of fatal accidents encountered nowadays in the construction business.

Those who are concerned in the construction of structures at the sites are all aware of the importance of this fact. They are always trying their best in providing necessary facilities to secure safe and stable footstands for workers, making arrangement of construction procedure in a way that workers are always assured to be safe and training the workers to be careful in avoiding any hazardous place.

But this is not enough as the number of accidents shows. Construction sites of structures are ususally so narrow and construction periods are so limitted that labourers are obliged to work in hazardous situations such as under where other labourers are hauling a heavy structural member. These conditions are beyond the reach of field engineers. In order to solve the problem effectively, it is necessary to have the cooperation of planners and designers of the project. These engineers are primarily preoccupied by the economical and safety aspects of structure itself. They are sometimes short of experience in erection works of structures, or they do not have enough time to pay their attention to the safety of workers who put their projects to the realization. But there are a lot of things to be taken into consideration at the early stage of the project planning affecting the occurence of accidnets in the later stage of the project realization. For example, preparation of large space in the structure in the design will allow easy handling of structure members in it at the erection stage, or attachment of provisionary supports for safety ropes in the fabrication will assure the safe movement of workers at the construction stage.

The concept of safety should be kept in mind not only by the engineers on the construction fields but also by the planners and designers of structure. The target of no fatal accident will be achieved by systematical incorporation of all safety measures into the design of structure and the implementation schedule of the project.

For this purpose, the causes of accidents should be clearly analized to enable all engineers concerned to find out where hazards are and to eliminate them. The Table 1 shows kinds of hazards and the ways to eliminate them.

The most direct way to bring the workers out of danger is the replacement of workers by machines equipped with remote control devices.

On several construction site of pneumatic caissons, digging of ground was carried out by excavation machines which were manipulated from outside of the caisson, and the process of excavation was observed again from outside by the use of industrial televisions. In a consequence there was no worker in descending caissons which were full of hazards before.

Similarly radio control bulldozers designed for the operation in the water relieved drivers of unforeseen dangers in rivers.

Table 1 Hazards and their control

Hazards	Prevention methods	Example
A Hazards involved in job itself (lifting and hauling of heavy objects etc.)	A1 Mechanization simple temporary members Mechanical instruments	Launching method of girder by mechanically descending device
	A2 Improvement of machines Safe guard system Amelioration of driving devices	Moment limitter, device to avoid overlifting Mechanically driver winch-hydraulic winch
	A3 Central control of operations	ITV
	A4 Remote control	Radio control
	A5 Improvement of working conditions	night works → daytime works
	A6 Simplification of works	Rivet → High tension bolt
	A7 Big block manipulation	Lump lifting of bridge member by floating crane
B Hazardous working places (high places, works in water, works in pneumatic caisson etc.)	B1 Prefablication and pressemble at risk-free places	Base carry Launching method of prestressed concrete beam
	B2 Strengthening and make-safe of working sites	
	B3 Remote control	Robot

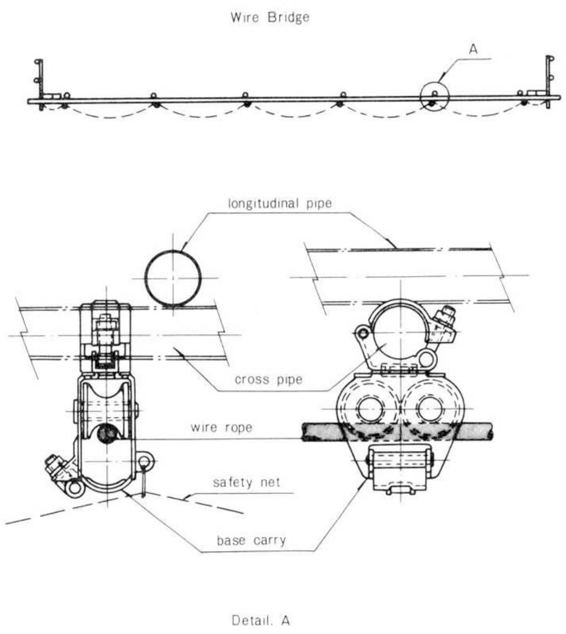
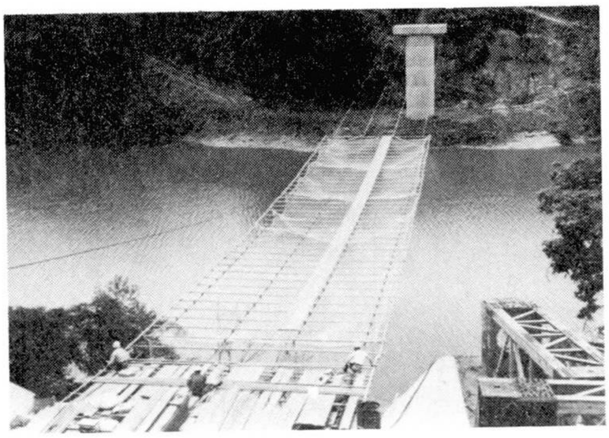


Fig. 1 Wire Bridge and Base Carry



Picture 1 Base Carry

The next step is the prefabrication of members or erction facilities outside of hazardous places. The setting up of safety net was quite a dangerous operation which bridge builders were obliged to overcome at the first stage of construction. This problem was solved by means of the safety net preassembled nearby places free from danger and then pulled out by guidance cables. (Fig. 1 and Picture 1)
Launching method of erection for prestressed concrete beams is widely used for the same purpose.

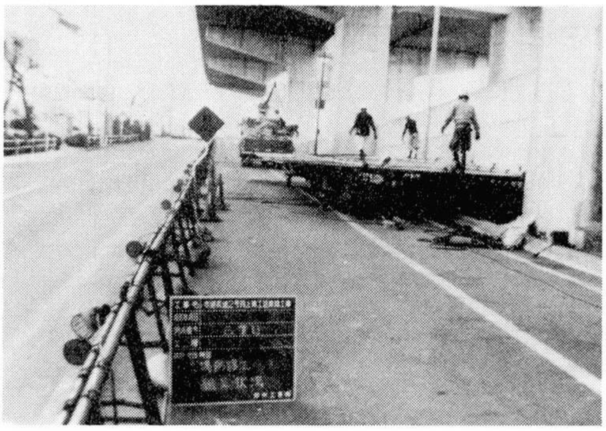
The simplification of fabrication and erection of structures is also of great importance in this respect. The lifting up of a long girder portion to its final position by use of floating cranes with big capacity is much easier and safer than long sequence of connection works of the small members for the same structure.

Another aspect of hazard control is based on the fact that construction works will be carried out more safely in daytime than at night.

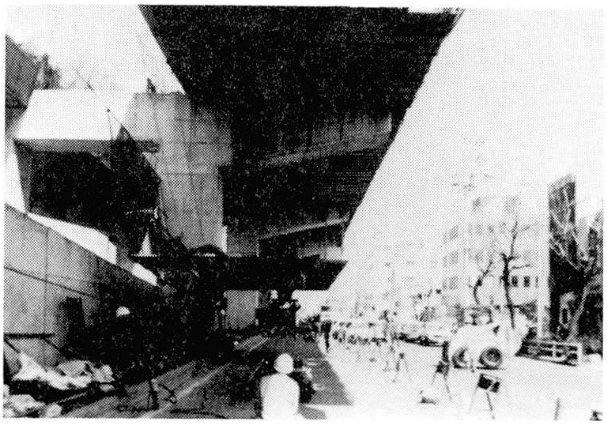
Coupled with the necessity of elimination of noise at night, one of principal public nuisances, the contractors who work for the construction of urban expressways in densely populated areas are forced to implement the major portion of their works in daytime in spite of heavy traffic circulating on the streets under the expressway projects.

Nagoya Urban Expressway Corporation is trying hard to solve this problem through various means and ways. Picture 2 and Picture 3 (with details illustrated in Fig. 2) show respectively a scaffolding and a beam to be used as a support of steel formworks for a cross beam of a pier. These temporary works are assembled within the narrow fabrication area obtained along the streets, then turned around and lifted or simply turned arround to theif final position during short traffic intervals while the traffic on the streets is stopped at the nearby street crossings. The construction of the permanent structures can be carried out continuously on these temporary works.

An erection system of a three span continuous girder for the expressway over a street was thought out. In this case, in order to avoid erection works over the street, the girder is assembled parallel to its final position over the fabrication space prepared in the center portion of the street where bent supports are allowed to be used temporarily. Then the girder is pushed horizontally to the



Assembling work



Lifting work

Picture 2. Scaffolding being lifted without any disturbance to the street traffic under the construction site

Picture 3. Construction beam for cross beam without any traffic disturbance

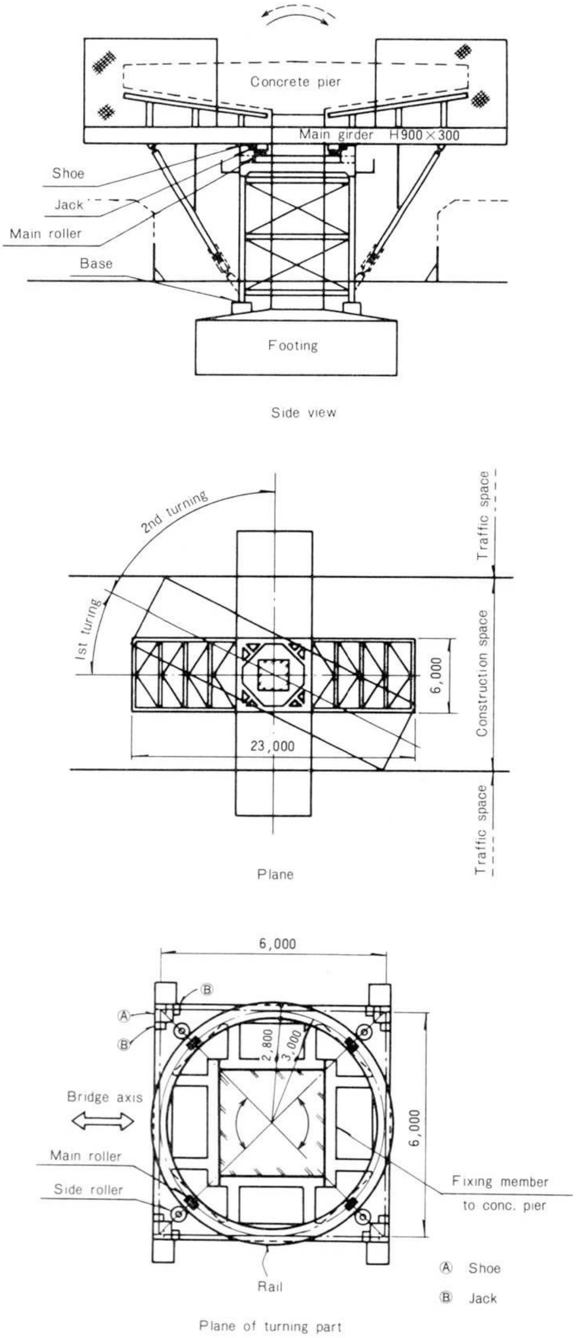


Fig. 2. Device to make constuction beam without any traffic disturbance

planned position by 4 oil jacks controlled and operated simultaneously. The horizontal hauling of the girder is allowed only while the traffic on the street is stopped by traffic signal of nearby street crossing, the operation as a result does not cause any disturbance to the traffic even when the traffic under the construction site is heavy.

In conclusion, the mechanization of construction is very effective for the increase of the safety of works. However, according to the above mentioned statistics, 30% of total accidents to death of workers in construction were caused by defects of equipment or malmanipulation of machines. It is necessary therefore to plan the project, to design the structure and to carry out the works for the proper and adequate use of machines in order to save the lives of workers.