

# **SAFETY EDUCATION IN CONSTRUCTION ENGINEERING**

*Tetsuo Hojo*

Professor, Monotsukuri Institute of Technologists, Japan

## **1. INTRODUCTION**

Construction industry has the highest labor accident rate among all industries, it is very important to study countermeasures for accident prevention. In the construction industry, the numbers of proportion for skilled workers decrease, while the aging of the worker advances, and non-skill and young workers increase. According to the accident statistics, it is shown that an accident rate is higher, as an experience is less. Therefore, persisting in the safety control through education, especially for young and unskilled people, becomes important.

Many of industrial accidents in the construction industry originate in the un-safe action type. The measure paid its attention to the factor that lurks the action on the worker side, as well as on the technical sides, is needed in the safety control. As a first step to examine measures for safety control, analysis on various human factors that exist in the background of an accident and a human error is carried out.

This research firstly introduces the measure about an industrial accident and a human factor, then analyses the near-accidents reports of the students in the Monotsukuri Institute of Technologists. At the Institute, the practical lessons are conducted on the outdoors under a similar condition to construction site. The students immediately after entered into the Institute have almost no professional knowledge, and they can be considered unskilled or a young worker in the construction industry from a worker's occupational capability point of view. Finally, some behavioral pattern of unskilled people and feature of a mind-and-body function are pointed out.

## **2. OCCUPATIONAL SAFETY AND HUMAN FACTORS**

### **2.1. Industrial accidents and human factors**

In order to prevent an industrial accident, it is necessary to examine the analysis and measures concerning various human factors that exist in the background of an accident and a human error, as well as hard measures, such as work environment, equipment machines, and construction technology. That is, it is important to work on the measure in consideration of the characteristic of the human being who actually works.

As for the definition of the human factors, it seems to be different by research objects such as aviation field and nuclear energy field, and it has been interpreted as "all the human factors in which equipment or systems are necessary in order to achieve the set-up purpose," in the general industry field. The problem concerning all the classes and processes that human beings, such as those who are engaged in the work of the site, those who take charge of a plan or a design, an administrator who superintends them, a business administrator, and a person in charge of administration, intervene is contained in the human factor of a wide sense.

Therefore, it is necessary to only analyze broadly the influence affect human action from viewpoints, such as a factor of not only the factor of an individual level but a group organization level and a social culture level, and to take a measure. Moreover, although human error, such as a worker's operation mistake, malfunction, etc., is originating and disaster is generated in many cases, there is a direct cause, indirect factor, and background factor etc. in resulting in an error. There is the tendency to pay one's attention only to an external direct cause was suited conventionally, when taking a measure, it is important to grasp clearly the human factor as an origin-factor in each process in the background.

In various fields, such as aviation industry, electric power industry, and chemistry industry, investigation research on a human factor has been done since before. In aviation industry, it is pointed out that many aircraft accidents resulting from the operation crew have occurred, and it is analyzed as the factor in connection with man increasing it relatively as the performance of relation in the generating factor of an accident between man and a machine of a machine and equipments improves with a time. Then, the approach of measures to give priority to a human factor is promoted internationally. Educational training of the research based on cognitive science or information processing theory, cockpit resource management training, and incident report system etc. is aimed to improve safety measures with a start.

In electric power industry, the necessity for the human factor research in nuclear safety came to be strongly recognized ignited by the nuclear power plant accident which occurred in 1979. In spite of having taken the multiplex protection measure in which double safety measures were given in huge technical systems, such as power plant, the cause of an accident has many things resulting from a human factor. In Japan, in the human factor research center established in the Central Research Institute of Electric Power Industry, the past fatal accident example is analyzed, a potential factor in back is extracted with a direct cause, and it is striving for recurrence prevention and before-it-happens prevention through development of the human error analysis evaluation technique of clarifying those causal relationship and working on a measure etc.

## 2.2. Human factors analysis method

The construction industry has respect where systematization and making to the manual cannot correspond difficultly and the safety facility enough because neither the content of work nor the working condition are constant. Therefore, the industrial accident generated by the construction industry has very many things resulting from un-safe action, and various researches have been performed from the viewpoint of human error prevention up to now.

An incident investigating method is effective to analyze human factors. This method includes pinpointing the source of dangerous which is latent there, and devising a preventive measure by collecting near-miss accidents phenomenon examples (near-accident experience, incident, etc.) which were the one-step this side, although it did not result in a real accident. There is Heinrich's law in the theoretical background of the incident investigating method, and it is based on the establishment distribution rule of the safe relation phenomenon. This means that the occurrence of one big accident is based on 29 small accidents and small trouble of 300 affairs and fault further without damage. That is, since there are small accident and trouble of being the dozens times and hundreds times many as this in the background which serious disaster generates one time, it means that it is important for disaster prevention to collect and analyze them, to grasp the tendency of incident which is easy to generate, and to take a suitable measure. In order to analyze the human factor in the background of a construction industrial accident, it is necessary to collect and analyze many near-accident reports including important information.

In a construction field, there are few cases of the operation which analyzed the human factor from such a viewpoint using the near-accident investigating method. In order to analyze the human factor in the background of a construction industrial accident, it is necessary to collect and analyze many near-accident data including important information. Then, the construction training in the Institute was considered to be the one work site, it considered that the student who is having training was a non-skillful worker or a youth worker, and near-accident investigation was conducted.

## 3. ANALYSIS OF NEAR-ACCIDENT REPORTS

### 3.1. Questionnaire surveys

Monotsukuri Institute of Technologists is a university of a new engineering system founded aiming at training of the talented people who can respond to the new science which studied synthetically the skill and technology which is to the foundations of the production of making things. Practical skill education, such as training, an exercise, etc. linking directly to the production of a thing, is thought as important, and power is directed also towards the management education which supports the leadership and floatation power at the site further. In basic process of the first grader, it aims at learning basic skill, and the technical technique and technical knowledge of construction at large. A second grader performs study which includes the engineering

technology and management required for construction engineering after the end of basic internship through a design and construction of the small-scale structure object which used various construction materials, such as wood, concrete and steel. In the third grader, in order to raise specialty nature in the field of "a wooden work", "structural engineering", and "finish and equipment", a series of contents from a design to construction are learned, building a structure.

The total number of students of one grade is about 180 persons. As for education system, one class consists of about 60 students, and one class members are divided into eight training groups, that is, one group unit is composed of 7 or 8 students. Training is performed under actual instruction of the members of teacher having excellent in skill and technology. For a safety control, tool-box meeting activities are carried out before practical training, a safe directions matter on the day, such as use of a helmet, safety shoes, and a safe belt, is checked. It carries out like the procedure currently carried out by the usual on-site work.

Questionnaire surveys of near-accidents to students of about 500, who newly entered into the Institutes within three years, were carried out. An investigation was carried out paying attention mainly to the factor of human factors, equipment, and a working method. The frequency and type of near-accidents were arranged and the behavioral pattern and state of mind in which it results were examined. At the investigation time, the first graders had the training experience of two months, the second for one year and two months, the third for two years and two months. In this investigation, experience between those three graders was arranged and differences of recognition and situation concerning near-accidents were analyzed.

### 3.2. Types of near-accidents

To examine in what kind of work the students, who are the beginner of construction dangerously encountered, the student's incident experience are arranged. The entire near-accident report number is 903, and type of work with a lot of number of cases is arranged.

Temporary work is the assembly and demolition of a scaffold and there are many possibilities of encountering disaster also in a special skillful worker. The same tendency is shown also about the student's near-accidents and it resulted in showing a large possibility of encountering danger. In order to make a student do the high risk work of such danger, the safe surveillance at the time of detailed safety education and work is performed, and it is shown that it is required to secure fundamental safety.

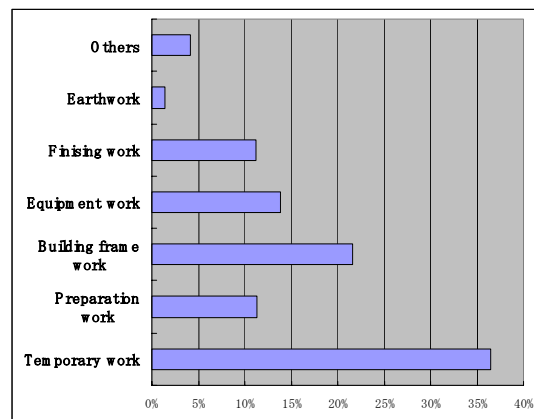


Fig.1 Types of Near-Accidents

In equipment work including woodwork, masonry, etc., the student of the Institute had an encounter experience of danger about these work to being what works without a skillful worker feeling danger. Since a skillful worker has full knowledge of the character of a tool, and the peculiarity of work and begins work, the possibility to have a disaster is relatively low. When a student is engaged in these equipment works, it is shown that student should practice after mastering fundamental skill, such as how to use the manual of work, and a tool, to some extent on the basis of instruction of a skillful worker.

In general construction, an earthwork with much serious disaster has extremely little near-accident number of cases of a student. This is considered to be because for there not to be use of a heavy industrial machine and a large-scale earthwork in practical lesson in the Institute. When a large-scale earthwork practice is made to experience in the Institute using a heavy industrial machine etc., the possibility of generating of serious disaster is large and can say that it is too risky compared with the educational effect by making work experience, and its necessity.

### 3.3. Analysis of mind-and-body function

The analysis result of the mind-and-body function when causing a un-safety action is shown in Table1. This classification is a method often used for analysis of the preventive measures of the human error in other industries, such as a manufacturing industry. These 12 items can be classified into four according to a mind-and-body function. That is, items 1-3 are functions of scene grasp, items 4-6, integration of thinking, items 7-9, feeling and emotions, and the items 10-12, work operation.

When the student is considered to be a beginner or unskilled people, the professional worker is considered to be an expert or a skilled people, and the feature is analyzed from the distribution of near-accident generating, the following things could be pointed out. In Table 1, professional worker's column analyzes 3,787 examples of an incident report in a manufacturing industry.

It can be said "not visible" is a human factor which falls similarly even if a beginner is also an expert. In the case of a beginner, "not noticed" and "forgot" are fewer than the experts, because basic knowledge and skill experience are originally scarce from the first. However, the item of "forgot" increases while studying after going up the grade year and obtaining knowledge. It is thought that beginner's characteristic is shown.

It is possible that it was carrying out as "didn't think deeply" took out the hand just or it was directed, without understanding well etc. It means that judgment is insufficient for this, and the expert has also become a factor with one of most errors. It is generated in order for the grade of danger to be fully unable to judge "seemed safe", or to become overconfidence and to make a self-taught judgment, and also generally it has become most experiences with the incident example.

The processing at the time of abnormalities, and when hard-pressed in time, it generates in many cases "panicked", and compared with an expert, a beginner can say that it is rare to encounter such a phenomenon. Moreover, the item of "tired" has few beginners and experts. Generally, although it is made not to make it engaged in work in many cases when condition is bad, since it has participated as a lesson in the case of a student, it is thought that these are peculiar to a student.

"did unconsciously" is a factor with this as big as 20%. With the increase in work experience, a numerical value tends to increase and the practice of work experience can say that it is making this kind of danger experience. The very big rate is closed compared with the expert, and a beginner's feature is shown. "hard to do" expresses the state of the skill level, and it can be said result which is beginning to look at a working condition calmly to increase rapidly as a grade becomes high. It is thought that it is shown that "unbalanced" has a numerical value as large as a low grade, and it is unfamiliar to the work to do.

	2nd grader	3rd grader	Students	Professional Workers
①not visible	5.8%	7.1%	6.3%	8%
②not noticed	11.4%	10.6%	11.1%	15%
③forgot	2.7%	6.4%	4.2%	6%
<b>( ①+②+③ ) scene grasp</b>	<b>19.9%</b>	<b>24.1%</b>	<b>21.6%</b>	<b>29%</b>
④didn't know	4.4%	1.6%	3.3%	1%
⑤didn't think deeply	13.7%	16.8%	14.9%	21%
⑥seemed safe	11.7%	10.1%	11.1%	22%
<b>( ④+⑤+⑥ ) integration of thinking</b>	<b>29.7%</b>	<b>28.5%</b>	<b>29.3%</b>	<b>44%</b>
⑦panicked	4.9%	4.1%	4.6%	9%
⑧unpleasant	0.2%	0.2%	0.2%	1%
⑨tired	6.1%	7.1%	6.5%	3%
<b>( ⑦+⑧+⑨ ) feeling and emotions</b>	<b>11.1%</b>	<b>11.5%</b>	<b>11.2%</b>	<b>13%</b>
⑩did unconsciously	22.6%	16.1%	20.0%	4%
⑪hard to do	8.8%	11.7%	10.0%	5%
⑫unbalanced	7.9%	8.0%	8.0%	5%
<b>( ⑩+⑪+⑫ ) work operation</b>	<b>39.3%</b>	<b>35.9%</b>	<b>37.9%</b>	<b>14%</b>
Total data	659	435	1,094	3,787

Table1 Distribution of near-accidents generating factor

### 3.4. Features of unskilled people

Table 1 is re-arranged according to a mind-and-body functional item, and what compared a factory worker's results of an investigation is shown in Fig.2. Here, the student was considered to be an unskilled people and the professional worker analyzed by considering a skilled people. Although it is thought that the contents of work and conditions have the influence of not being the same, the tendencies of the generating factor seen according to the mind-and-body function of an unskilled and a skilled people differ considerably. In the case of the unskilled people, the generating factor has become with the order of work operation, integration of thinking, scene grasp, and feeling and emotion, but in a skilled people, integration of thinking and scene grasp, occupy more than 70%.

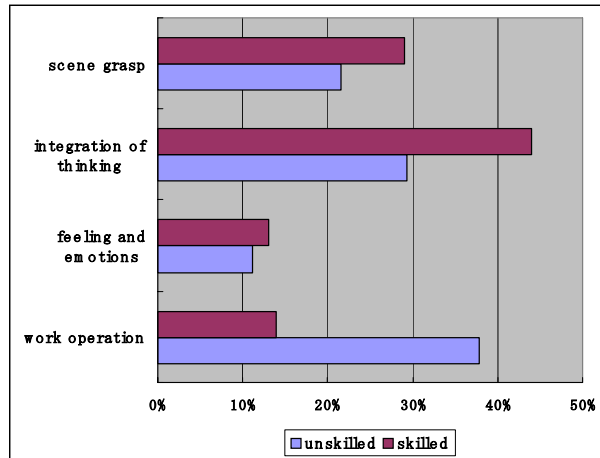


Fig.2 Comparison of Mind-and-Body Function

Generally, un-safe action has most frequency where recognize things and they are generated in the process to judge, like in the case of a skilled people. According to Fig.-2, since the scene grasp function of cognition or memory is inadequate, it is considered to result in a judgment mistake in many cases. An expert is abundant in knowledge and experience, since skill level is high, may bypass integration of thinking from practice and may move to action reflectively. Un-safe action may arise by this reason occasionally for them.

On the other hand, in the case of an unskilled people, there are few factors of integration of thinking and scene grasp, and it has most factors of work operation. As compared with a skilled people, the unskilled people have a tendency to take action before grasping or judging a situation. This difference is conjectured that mastering level of skill, the degree of the practice to work, etc. are the influences by the low thing compared with a skillful worker. That is, the non-practice in the work itself serves as a big element, and it can be said that the unskilled people is acting without the ability recognizing the whereabouts of danger. Thus, the factor of "did unconsciously" that to an unskilled people seen is considered because fundamental skill and knowledge are insufficient.

This is the big feature of an unskilled people and shows the necessity for safety education. Although there is nothing at the reason for the ability to be said to be what showed result with this not necessarily sufficient investigation, it is thought that the characteristic of an unskilled people is shown.

## 4. CONCLUSIONS

In this research, after analyzing the present condition concerning an industrial accident, the feature of the industrial accident in the construction field, and the situation to the accident prevention measures from the human factor side in each industrial field was introduced. In the construction industry, un-safe act type disaster was occurring frequently, and the necessity of clarifying the potential factor, which results in human error, and taking a measure with emphasis on a human factor side was pointed out.

Questionnaire investigation about near-accidents was carried out for the student who performs construction training lessons in the Institute. From the result of questionnaire survey, a part of behavioral pattern of unskilled or a youth worker and feature of a mind-and-body function were found out.

1) Existence of near-accident experience had a large degree of influence by the difference of experience, and has grasped that the recognition to danger changes a lot in connection with it. Also in construction training lessons of a university, it became clear that there was the same incident experience as a construction site, and it had anew a new appreciation of the importance of a safety control.

2) As a result of analyzing a mind-and-body function, it was shown that there is most frequency generated in process of work operation as a generating factor of incident in these results of the investigation. Before

grasping or judging a situation as compared with an expert, the tendency to move to action is shown. That is, the non-practice in the work itself serves as a big element, and the tendency of an unskilled people to act as the whereabouts of danger is not known is strong.

3) It can be said that it is the feature of the unskilled people that a surrounding situation cannot fully grasp but overlooks a dangerous factor, since it is unfamiliar and unskilled, judgment is mistaken, and since it becoming difficult to make a suitable judgment or knowledge is insufficient. To the unskilled worker, it is necessary to take into consideration the measure against a safety control based on these results.

This investigation is a new trial in the engineering education of an academic field. There remain also many future investigation subjects, such as basic data and the contents of analysis. For example, it is required to analyze the back factor in detail with correlation between near-miss accidents and experience or ages, existing accident example or phenomenon etc.

There is a view by which the correspondence level of safety management is evaluated by four stages from a human factor side. According to it, level 1 is classified for the fundamental measure stage, level 2 for analysis or measuring stage from a human factor side, level 3 for before-it-happens prevention stage of a similar accident, level 4 for foreknowledge or measure stage of a new species accident. According to this appraisal method, it is thought that the safety measures as which aviation industry, electric power industry, etc. considered the human factor are the stages that shifted to the level 3 from the level 2.

On the other hand, it can be considered the stage, which the level 2 started in the construction industry. A many-sided case collection, making database, and sharing it are requested to study in the future. This study is the first step, the investigation analysis of many work types and a different field of a broad age group is required for it. By continuing such investigation in several years from now on in order to make database, it is considered to be connected with improvement in the safety of future construction industry with expansion of the safety control in engineering education to take the measure to an unskilled people or a youth worker.

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