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Human Factors in Safe Construction of Mega Projects in India

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Abstract: Construction is a hazardous process, which is responsible for severe and fatal accidents around the world. The global studies on Occupational Health and Safety (OHS) aspects in the construction industries also reiterated for the improvement of safety culture. The mega projects are projects characterized by vast capital, unorganized work force, technically complex constructions, and having a significant impact on the socioeconomics and community development. For example; highways, power projects, residential buildings, airports, industrial parks, etc. The construction industry is mainly skill oriented and labour intensive. This paper is aimed at studying the prevailing safety practices in the construction of infrastructure power projects in various regions in India in the past 15 years.

The study mainly focused on a survey of human practices which are responsible for the behavior at work. The unsafe acts/conditions at work place when uncontrolled lead to incidents/ accidents. The elements identified in the construction process are factored and a project safety culture cycle program is developed. This program is based on rock-bottom principles, rigorous approaches and rigid hazard management practices, which is suitable for the construction industry.

Keywords: Hazard Management, Occupational Health, and Safety (OHS), Mega Projects, Safety Culture.

I. INTRODUCTION

The construction industry worldwide is a complex and a hazardous industry. The industry employs large scale of illiterate / semi-literate, unskilled/skilled, seasonal and high mobility work force. The industry is also unorganized, to the extent that the fair principles/practices of collective bargaining and workers participation in safety are apparently not visible. Due to this fact, the safety conscious work environment is not visible. Progressively responsible governments worldwide are undertaking massive mega infrastructure projects like power, oil, and gas, transport, high ways, railways, airports, etc, for their social and community development. Megaprojects in infrastructure sector have been instrumental in the transformation of the economy of a nation.

The definition of a mega project according to Bent Flyvberj [1], are those projects which cost more than USD 1 billion, take 5 years to move from design stage to operation stage, have to impact on more than a million people and have transformation impact on the area in which project is located. Megaproject typically involves 5-10 years to go from design phase to operational phase, and also technologies and policy keeps on changing frequently to accommodate the complexities involved in these kinds of projects. The construction period normally varies from 5 -10 years or even more, to ensure safety during the entire construction period is a challenge and a herculean task.

The construction industry is recognized dangerous by its nature and has high accident rates, which result in absence from work, loss of productivity, permanent disabilities and even fatalities [2]. Besides causing human losses construction accidents affect project progress, increase costs and damage the reputation of the builder [3]. The investigation and analysis for root causes are essential in the construction industry to prevent incidence/recurrence of severe accidents.

The objective of the study is to understand and assimilate the trends in the accidents that have taken place in the mega construction projects in the last 15 years in India. The literature survey for the last 30 years and before on the concepts of safety management system, safety climate, and safety culture the latest which has emerged from the Chernobyl nuclear accident (Former USSR) in 1986 is carried out. The term safety culture has crept into all industries namely nuclear, transportation, space & aviation, oil & gas, hazardous chemical processes, etc. and even, of late into construction also in a small way.

A Hazard is a situation in the workplace that has the potential to harm the health and safety of people or to damage plant and equipment. The situation could involve a task, chemical or equipment used. Hazard management is a continuous process that can be used to improve the health and safety of all workplaces [4].

Hazard Management is essentially a problem-solving process aimed at defining problems (identifying hazards), gathering information about them (risk assessment) and solving them (risk control). This is followed up by checking to see that the controls were successful (evaluation) and reviewing the whole process (review) after a period of time or when something changes [5].

A simple way of describing the hazard management process is the SAFER approach:

See it (identifying hazards)

Assess it (risk assessment)

Fix it (risk control)

Evaluate it (evaluation)

Review it (review).

Risk, in relation to any potential injury or harm, is the likelihood and consequence of that injury or harm occurring [6].

Risk Management is the identification, assessment, and prioritization of risks (defined in ISO 31000) as the effect of uncertainty on objectives) followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities[6].

The construction industry is a dynamic, short period lasting/seasonal, temporary, unorganized and to a larger extent less controlled. The work force deployed in Indian construction industry is poor (below poverty line) , illiterate / semi –literate, unskilled / semi-skilled, under / unnourished, migratory, exploited (risk takers), with barriers in communication, less or no commitment, lack of health care/ medical facilities and are working in a contract system. The persons working under such unabated circumstances/constraints have the high potential to meet with the severe/fatal injuries at work places. The safe working environment in construction sites is a rare phenomenon to be observed. This situation is probably due to short of leadership in safety and lack of consideration of human factors. The institutional, untiring efforts are required to improve the safety in the mega projects.

A research study on the development of an integrated safety culture model in the construction of mega power projects was conducted. The findings of the study are presented in the paper.

II. WHAT IS A SAFE CONSTRUCTION

A. Meaning of Construction

In the Indian context, the meaning of "Building or other Construction Work" means the construction, alteration, repairs, maintenance or demolition- of or, in relation to, buildings, streets, roads, railways, tramways, airfields, irrigation, drainage, embankment and navigation works, flood control works (including storm water drainage works), generation, transmission and distribution of power, water works (including channels for distribution of water), oil and gas installations, electric lines, wireless, radio; television, telephone, telegraph and overseas communication dams, canals, reservoirs, watercourses, tunnels, bridges, viaducts, aqua ducts, pipelines, towers, cooling towers, transmission towers and such other work as may be specified in this behalf by the appropriate Government, by notification but does not include any building or other construction work to which the provisions of the Factories Act, 1948 (63 of 1948), or the Mines Act, 1952 (35 of 1952), apply [7];.

B. Safe Construction Principles

The construction work place should be designed in such a way that accidents/ injuries are prevented. The design should also be based on sound safety principles which are well accepted by all levels of the work force. Typical construction safety principles identified for the study to enhance the organizational safety performance and effectiveness are listed below.

A construction industry should be openly and transparently committed to the principles of best practice in its organizational safety culture. These safety principles are intended to be operated at an industry level and establish broad values by which contractors / sub-contractors /sub-sub- contractors /etc should operate. They also establish a foundation for the development of shared understandings among all stakeholders on the importance of safety and the development of a safety culture in construction projects. The term 'safety culture' was first used in International Nuclear Safety Advisory Group (INSAG), International Atomic Energy Agency (IAEA) (1988) 'Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident' where safety culture was described as: "That assembly of characteristics and attitudes in organizations and individuals which establish that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance."[8] The usage of the term safety culture has crept into practice in all industries like aviation, oil & gas processing, hydrocarbon processing, health services, etc including of late construction.

The construction safety culture for the purpose of this study is stated as "An attribute encompassing behaviour and commitment of all the workers, supervisors and managers in achieving a safer working environment and creating a safe place for construction of Mega Projects. Typical Construction safety principles are listed below which enhances the organizational performance

1. The principle of Safe construction through:

a. Design for safe construction
b. Planning and procedure development for safe construction.
c. Engineered features for housekeeping during construction.
d. Use of appropriate plant and machinery and construction systems.
e. Learning from good and bad construction practices in similar construction works.
f. Safe Work Procedure development and enforcement of procedure compliance.
g. Role of supervisor leadership.
h. Perpetual reminders on safety through safety messages.
2. The principle of learning through effective communication (at all levels).
3. The principle of safety leadership and commitment (by authority, responsibility, and accountability at management and all other levels).
4. The principle of walk and talk for safety (for all levels of the work force).
5. The principle of participative and cooperative safety culture among construction participants (institution of Brother Keeper concept in a construction site).
6. The principle of empowering the workforce by training on the hazards of construction activities and safe construction practices.

C. Overview of Construction Safety Culture

A safety culture describes a shared set of organizational values, assumptions, and beliefs. It is characterized by high levels of communication, confidence, and trust between the project stakeholders and constructors. One threat to the development of positive safety cultures is a lack of inter- and intra- organizational understanding of the importance of safety. It is critical that senior managers of all project participants actively demonstrate their commitment to safety through participation in their own organization's health and safety management processes and the allocation of safety responsibilities from senior management to the work force.

The major aim of the study undertaken is to encourage project stakeholders (i.e. client, designer, etc.) and constructor to work collaboratively and continuously throughout the project life to achieve the highest possible standards of project safety management. The designer and constructor should be engaged as early as possible so that they can provide their inputs into the project safety master plan. They, in turn, should include their subcontractors and suppliers as early as possible in planning for safety. Within projects, clients should drive strong and positive safety cultures through their procurement processes. All efforts should be made to ensure that the major stakeholders work constructively to allocate responsibility for safety appropriately and to integrate safety considerations into all project decision- making. Experiences suggested that, in those cases where safety best practice was identified, a high level of integration and participation was a key factor in improving safety outcomes in the construction project. Project safety should not be a 'blame game'. An incident that could have been avoided on a construction site reflects poorly on all project stakeholders, and it is important that a just and fair allocation of responsibility for eliminating or reducing safety risks exists within construction project teams.

D. Elements of Construction Safety Culture

The key elements of safe construction in a mega construction project are:
1. Management commitment and care for safety and promotion as a value at work place
2. Leadership for safety in construction works
3. Accountability and responsibility for safety at various hierarchical management levels
4. Open & transparent hazard information/communication, fair and blame-free reporting of work environment both vertically and horizontally and identification of unsafe acts and unsafe conditions.
5. The pace of decision making to improve safety in work environment.
6. Maintaining high ambition and setting of high safety goals in construction works

III. APPROACH TOWARDS SAFE CONSTRUCTION

The safety culture is state of science and art concept which is multi-faceted which involves multi-disciplines right from anthropology to advanced engineering/technologies in reducing the risk potential. The approach to this study is based on human engineering aspects which consider human behavior at work coupled with engineering solutions for the control of hazards at construction sites.

The approach in eliciting data for the study is Top-down and Bottom –up which is percolating the safety information/hazard communication from the top management level to the workforces' level and the feedback/suggestions / participation from the work forces level to the top management. This two –way approach ensures equal participation, commitment and involvement from all levels in the project and create a consultative- participative culture. The third dimension, namely lateral/horizontal level participation and involvement can be ensured by soliciting information from peers, colleagues, specialists, etc.

The information collected on human factors influencing project safety cycle from various sources is collated and analyzed. The findings of the study are presented in this paper.

IV. METHODOLOGY OF STUDY

A. General

An extensive survey and review of literature available at a national and international level on construction safety were carried out. A very limited current data is available on the injuries in the construction sector. It is noted that the "under-reporting or

non-reporting of injuries to the state / national governments or regulatory bodies has been commonly observed". Due to mushrooming of construction activities in infrastructure sector around the world, the governments with the limited resources are not able to keep up the pace with the developments and challenges. The period under the review /survey was for the last 30 years, where evolution and lot of developments nationally and internationally have taken place in the field of safety management system. The author has begun a career in the construction of a heavy chemical processing plant. The first-hand experience on safety at construction sites over the last 30 years in various capacities from a safety professional to a regulator is also incorporated in the study The data required for carrying out the study was obtained from primary and secondary sources.

The method /techniques of data collection adopted for the study is presented below.

1. The primary sources are :
   - Observation – Participant & Non-participant
   - Interviewing (Telephonic & Direct personal) – Structured & Un-structured
   - Questionnaire - Mailed & Direct personal
   - Opinionnaire – Mailed & Direct Personal.
2. The secondary sources are:
   - Government / Corporate / Academic / Consultant Publications
   - Published Safety Performance Reports
   - Research Reports/ Papers
   - Web search
   - Published Accident Investigation Reports
   - Group Study Reports
   - Journals / Text books/ Records, etc

The information obtained in the process of literature review/survey is utilized for preparation of this paper.

A. *Trending of injuries* Figures

The data on accidents that have happened in the last 16 years(2001-16) a group of around 36 units which comprises of construction units, chemical operations/processing plants, power generating units, engineering/fabrication units, research & Development units, etc was available. About 50,000 persons were employed and around 135 million man –hours were clocked in different parts of the country. Interestingly on an average in the last three years (2014-16) about 13, 500 persons were working in mega construction projects which recorded around 4.5 million man hours. This data was analyzed as per Indian Standard (IS -3786: 1983 (re-affirmed in 2002)) [9] for establishing the trends, to arrive at the preventive measures and strengthening the safety management system within the group.

B. Metrics of Safety Performance

The safety performance of an organization is measured in terms of rates which are computed based on a number of persons employed and the man –hours worked by them during the period.

The most common rates which are computed in the organization for reporting the safety performance are:

1. Frequency Rate(F)
2. Severity Rate (S)
3. Incident Rate (I)

The injury causing disability for more than 48 hrs. (2days) is considered as reportable injury. The formulas for computation for the above rates are given below:

1. Frequency rate (F):

No of reportable lost time injuries = A
Million –man hours worked= M
Frequency rate = FR

$$F = A / M \qquad (1)$$

Fig 1 gives the plot of frequency rates over the years. The F is a number which indicates the state of health and safety at a workplace. It is an indicator of the person's chances of getting injured with the number of hours of exposure to the hazard. It also provides an idea about the organization's efforts to protect the workers from work related hazards. It is a reactive and curative indicator which informs the organization's performance in safety after the accident has taken place. This also called as a Lag Indicator.

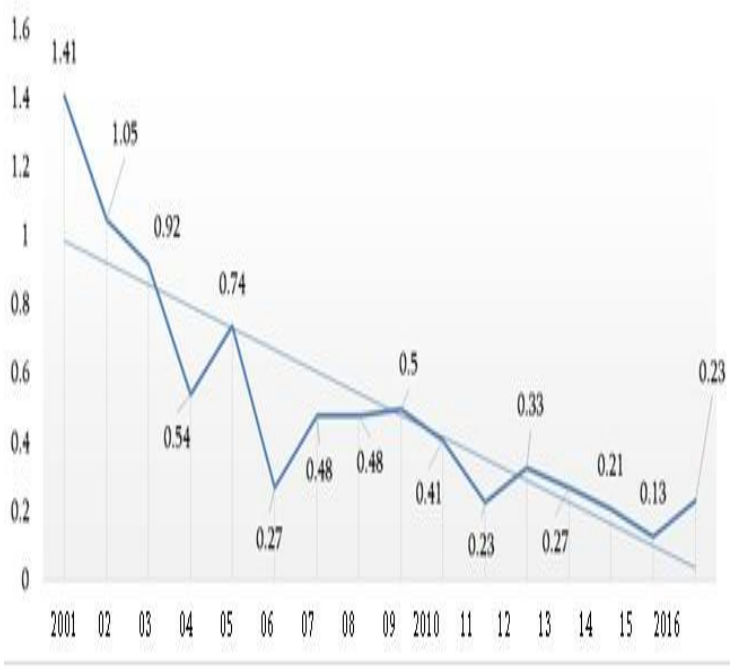

Fig 1 Yearly Trends in Frequency Rates (F)

The author's experience is that the Fs at mega construction projects, in general, are comparable with other hazardous industries.

2. Severity rate(S)

No of man –days lost = N

Million –man hours worked= M

Severity rate = SR

$$S = N / M \qquad (2)$$

Fig 2 gives the plot of severity rates over the years. The S shows the extent of safety anomalies by revealing how critical/severe the injuries and illnesses are. The severity is fortuitous / chance. In construction industry, this is a critical factor because the injuries are severe and fatal. The theory is that an employee who takes the time to return to work after injury had a more severe problem than one who can return immediately.

The author of the review of reports of mega projects has observed that though the F is comparable the S is high number due to severe injuries and fatalities.

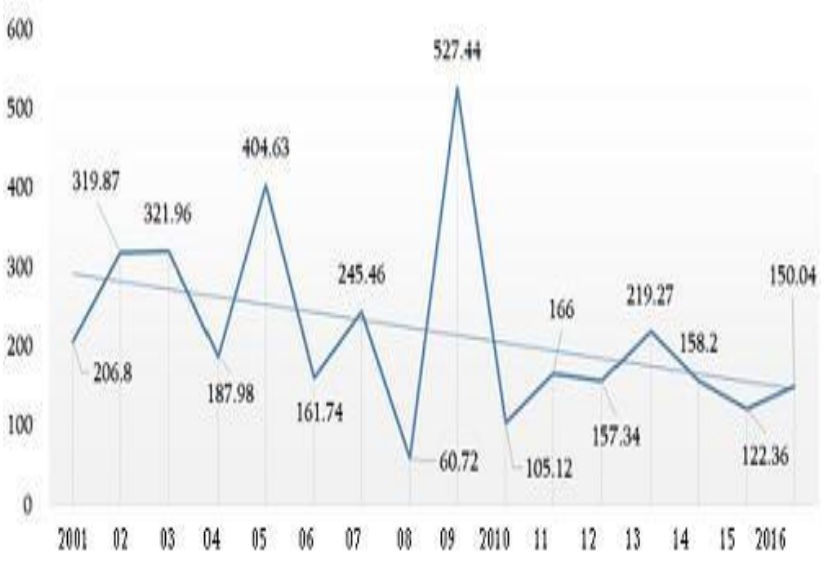

Fig 2 Yearly Trends in Severity Rates (S)

3. Incidence rate (I)

No of reportable lost time injuries = A Average number per 1000 persons employed= P

$$I = A / P$$

The I is used for inter group/trade comparison purposes between different kinds of work forces who are exposed to hazard. This metric also gives the susceptibility to injury. This parameter is analogous to prevalent rate in occupational health.

The trend in I is similar to F, hence no separate graphical representation is presented.

There was a progressive decreasing trend in F from 1.4 (2001) to 0.2 (2016), the S from 206.8(2001) to 150.0 (2016) and I from 3.2 (2001) to 0.6 (2016). The latest F, S and I reported for mega construction projects are 0.07, 5.0 and 0.2 respectively. It was observed that the trend is approaching stability/steadiness, and asymptotic (parallel to the x-axis). The decreasing trend is due to technological advances/developments, improvement in safety management system and human performance. A further study and review of the trends were conducted to identify human, organizational and technical factors which would improve the safety performance and reduce the occurrence of accidents/injuries further, in order to achieve zero accidents/injuries goal. On discussion with key players like managers, line supervisors, peers, workers etc., it was observed and inferred that due to limitations and constraints in technology and resources further improvement in reducing severe/fatal injuries is possible by enhancing human performance. Hence, the human factor is critical to further reduce the accidents / personal injuries and improve the safety culture.

V. CONSTRUCTION SAFETY –HUMAN FACTORS SCENARIO

The construction industry is a skilled based organization where human factors like knowledge, awareness, perception, attitude, behavior, motivation, etc play a key role as compared to organizational and technical/technological factors. It is has been established by the investigation or analysis of all past accidents that have taken place around the globe that the human error is the root cause of all accidents irrespective of any sector. The consequences of human error in process industries(nuclear, oil& gas, etc) is likely to cause colossal losses in terms of lives, property and the reputation or good will of the industry. The human error in the construction is likely to result in a severe injury or fatality to an individual or a group, due to the collapse of working platform or, casting concrete slab or caving in of excavated material, etc).

A. Human Factors (HF)

Human Factors (HF) means factor(s) that influence human performance as it relates to the safety of the mega project during the construction stage. The HFs are the following:

- Human capabilities
- Human constraints
- Perceived work environment
- Motivation
- Individuals understanding
- Emotions, etc.

B. Organizational Factors (OF)

Organizational Factors (OF), means factor(s) pertinent to the performance of an organization that influences the safety of the mega project during the construction stage. The illustrative OFs are the following:

- Vision and objectives
- Strategies
- Integrated Management System.
- Operating Experience Feedback
- Continuous improvements
- Priorities
- Knowledge management
- Communication
- Contracting
- Work environment
- Culture, etc

C. Technical Factors (TF)

Technical Factor (TF), means factor(s) relevant to the technology that influences and aids in the safety enhancement during the construction stage of the mega project. The illustrative Technical Factors are the following:

- Evolving / latest construction science & technologies
- Latest trends, strategies & methods in design
- Information / communication technology
- Evolving and advanced Specifications
- Quality assurance of material, engineering & supervision
- Improvements in Plant & Equipment, etc

Three stages of construction, viz., pre-construction stage (conception , design , detailing , vendor evaluation , work awarding, etc), construction stage (land development, excavation , concreting , erection./ installation of structures , systems and components) , post –construction stage (testing / qualifying structures , systems and components including commissioning up to operation stage) are considered for mega projects.

The pre-construction stage is a passive stage where designers, vendors, policy makers, project proponents, etc are involved to a large extent. The prevention by design concept by considering human factors (work place design, ergonomics, etc) can be adopted which takes care of safety during the entire construction stage and thereafter. The pre-construction stage lasts for 3-5 years prior to the construction stage. The work force in this stage is normally about 50, deployed in closed and cozy ambiance. No occupational hazard or risk is involved at this stage.

The construction stage is an active stage. This stage of the project has the longest gestation period of 5-10 years. The safety has the key role in this stage. The project safety management system should be well established and operative at this stage. The project management should consider human factors intensively and extensively during the execution of the project. Historically, the author has observed that many severe and fatal injuries have happened and reported at this stage only. The underlying reason is that about 7,000 – 9,000 (peak) contractual work force mostly illiterate and unskilled within the age group 20-35 years who are emotional, enthusiastic and chance takers will be working at the project site. The institutional control of the project management through authority, commitment, supervision, and responsibility is absolutely essential at this stage and often found lacking in the literature. This needs to be improved. The different levels of work force namely, workers, supervisors and managers commitment and participation in safety programs is required. High risk is involved in this stage.

The severe/fatal injuries, typically which have invariably happened and reported during the construction of projects in all parts of the globe are listed below. The study and analysis of all types of accidents that have taken place in the last 15 years (2001-16) in the construction projects have revealed that the three main types of accidents that have led to severe/fatal injuries are:

1. Fall from height (45-55 %)
2. Fall of / struck by or against by an object (30- 50%)
3. Exposure or contact with electricity or steam, etc (25-35%).

The single cause of all the above is the HF (human failure) on the part of project management to control the work environment through organizational and technical/technological measures.

The post -construction stage is a physical completion stage of the project where all structures and systems are in place and component level works may be in progress. This is the pre- commissioning stage continues up to the commissioning stage and beyond up to operation stage. This stage is an inherently safe stage, about 100-200 operation, and maintenance staff is involved and few contractor workers in the range of 200 – 500(peak) will also be associated. There is a mix work force. At this stage, persons will be working on systems where established and approved procedures are in place and also interfacing with construction group is there. The author has observed that few incidents have taken place at this stage due to inter and intra group, improper coordination and communication gap between the contractor personnel and the project personnel. This stage has a significant impact on HF as highly qualified and semi –literate/illiterate persons will be working in tandem. The project management shall ensure that the jobs are executed in a safe manner through effective supervisory controls. This stage normally lasts for a short period 1 -2 years which can be monitored and controlled. The risk at this stage is moderate.

The three types of accidents which are cited above, have their potential in the construction and post –construction stage. The author observed that the exposure or contact with electricity, steam, etc is a predominant hazard at this stage.

The human behavior at work dictates the safe method of work during construction. The HFs dominate the PF and the TF. An approach integrating OFs and TFs with HFs is essential to ensure safe construction of a mega project. The current trends and the thinking of project proponents globally is towards human factors - related approach towards occupational health and safety.

VI. DATA COLLECTION & ANALYSIS

A questionnaire survey presented in Table 1 was conducted by the author to establish the role of HOFs (Human and Organizational Factors) in developing a safety culture in the organization.

A total number of respondents (N=96) which includes, managers, designers, researchers, project proponents, constructors, contractors, etc participated and responded to the questionnaire. 10 questions covering various aspects of human and organizational factors were posed. The questions cover areas like humans responsibility, management commitment, integration of HOFs, employee's behaviour , management leadership, history of past accidents, communication, work observations, root causes, accountability and responsibility towards human factors.

The response to the questionnaire was obtained in a Likert Scale which consists of 10 Likert items. This is psychological measurement device that is used to gauge opinions, values, and views on a subject. It functions by having respondents to complete a questionnaire that requires them to indicate the extent to which they strongly agree or strongly disagree with a series of statements by choosing one of five point options.

The format of a typical five-level Likert item using 5-point scale used for collecting data is given below is:

A: Strongly disagree
B: Disagree
C: Neither agree nor Disagree (Neutral)
D: Agree
E: Strongly agree

Neither ranks nor numerical values are given to responses at present. Only the number of respondents for each Likert item is indicated in Table 1. The percentage response for each item in the range of strongly disagree to strongly agree are presented in Fig 3.

The following statements are inferred from the graphical representation;

1. 65.6% respondents Strongly agree with the statement that "Management can improve the human safety at work by a good training program"

This indicates that management should be more committed to arranging and involving workforce in training on safety at work on a continuous basis in mega construction projects.

2. 65.6% respondents Strongly agree to "Ensuring the safe work environment involves integration of human, organizational and technological factors"

The integration of human, organizational and technical/technological factors is absolutely essential to ensure safety conscious work environment in construction projects.

Table 1

SURVEY QUESTIONNAIRE ON "ROLE OF HUMAN & ORGANISATIONAL FACTORS" (HOFs)

No	QUESTION	RESPONSE (N=96)				
		A	B	C	D	E
1.	Humans are only responsible for the incidents / accidents?	1	17	9	31	36
2.	Management can improve the human safety at work by a good training program.	-	--	4	28	63
3.	Ensuring the safe work environment involves integration of human, organizational and technological factors?	-	-	6	28	60
4.	Employee's behavior at work can be changed if the management's attitude towards safety is honest.	-	-	5	30	58
5.	Safety can be improved by strong leadership and visible commitment by the management team.	1	-	4	32	58
6.	There is a human tendency to forget past incidents / accidents?	2	10	10	47	27
7.	Transparent, blame –free and open communications between management and workers improve HOFs.	-	1	7	37	
8.	Observation at work by supervisors will improve safe	-	1	4	37	52
9.	Do you believe that root cause of all accidents is human error which can be prevented by suitable training programs?	-	2	17	38	36
10.	Accountability and responsibility towards HOFs should be defined at Each level in an organization	-	4	5	48	40

3. 60.4% respondents strongly agree to the items that:

"Employee's behavior at work can be changed if the management's attitude towards safety is honest"

and

"Safety can be improved by strong leadership and visible commitment by management team"

The above two items are human and organizational factors which control the safety culture at the construction projects.
The study reveals that the project manager should be honest and committed to change the behavior of workers and contain risk–assumes / risk – takers at work so that accidents can be prevented. The strong leadership with visible commitment is the backbone of the success of safety management system at mega construction projects.

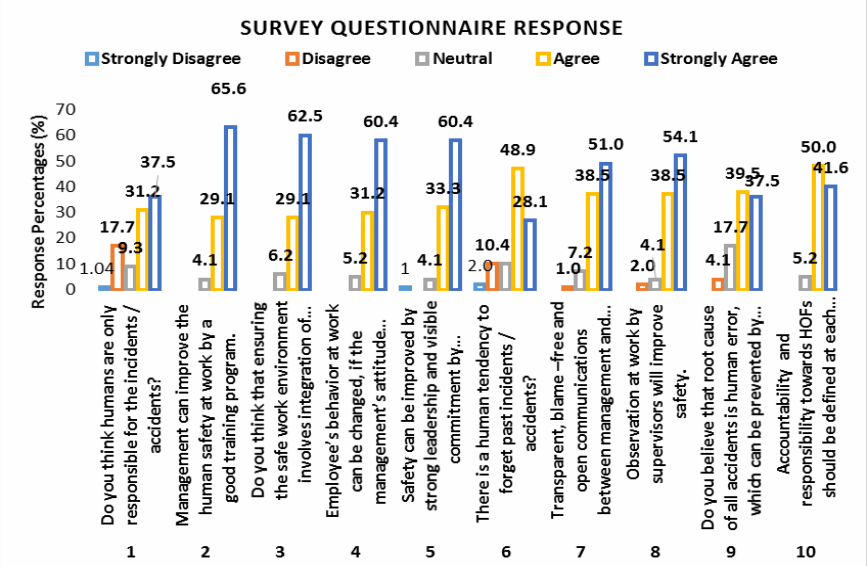

Fig 3 Role of HOF in Developing a Postive Safety Culture in an Organisation

4. 54.1% (Strongly agree) & 38.5% (Agree) to the fact that " Observation at work by supervisors improves safety"

The supervisors should visit the workplaces and observe the practices being followed. This is a success formula for safety at work but to the author's personal experience, invariably supervision is absent or supervisor is not aware of the work at many instances and especially during accidents.

5. 50.0% (Agree) & 41.6% (Strongly agree) to the fact that "Accountability and responsibility towards HOFs should be defined at each level in an organization"

Accountability and responsibility at each level in a mega project should be clearly defined. The interfacing between project construction group and the contactors is very vital. It is observed by the author that the accountability and responsibility towards safety at contractor level are getting diluted at the execution level due to cubbies (sub – contractor / sub-sub-contractor, etc).

6. 39.5% (Agree) & 37.5 % (Strongly agree) to the fact that " The root cause of all accidents is human error, which can be prevented by suitable training programs"

The successive and progressive investigations and an analysis carried out globally for accidents revealed that human error is the root cause of all accidents. The management should identify the active and latent weaknesses in their safety management system through periodic reviews and institute a robust systematic training program for all levels including the contactors.

7. 31.2% (Agree) & 37.5 % (Strongly agree) to the fact that "Humans are only responsible for the incidents/accidents"

Human inactions (omission/commission) like lack of supervision, communication, direction, motivation, etc are responsible for the accidents. This can only be taken care of if human factors are given due consideration along with the project related activities.

VII RESULTS & DISCUSSIONS

The study elucidated in the report high lights the need of an integrated Project Safety Culture Cycle Program (Fig.4) encompassing human, organizational and technical/technological factors into the management process. This is essential for the successful and safe construction of mega projects.

Fig 4. Project Safety Culture Cycle

There are five steps in the cycle, they are safety policy & program, project safety planning, organization structure and resources, monitoring, evaluation and bench marking, project management review and analysis.

The project management intent and commitment towards the safe construction of the project starts from the policing and programming of the activities. The HOT factors should be given due consideration at this stage. The safety as a value and priority should be the motto in the planning process. The project management should organize and structure the system with adequate resources considering the human factors. The periodic monitoring, evaluation and benchmarking of system performance should be carried out. The improvements required in human factors should be considered in re-defining the policies and programs.

Human factors in the context of occupational health and safety in a mega project, have been outlined as: 'site constraints enveloping the perceptual, physical and mental capabilities of work force and the interrelationships, interactions and interdependencies of individuals with their tasks and working environments, the influence of plant, equipment, and system design on human performance and those organizational factors which impact the safe behavior at work'.

Generally, the workers are influenced by a range of factors at work. The main areas of influence at work, are the project organization, the work, and human (individual) factors. These areas are directly affected by, communication mechanism within the organization; and the systematic approach to training. These are mainly focused on preventing human error.

These factors are illustrated as below:

A. Project Organization

The project organizational characteristics which influence safe behavior are:

- The necessity to promote a positive culture in which health and safety are seen by both project management, contractors and workers as being fundamental to the project's daily activities. i.e. they must create a safety conscious work environment.
- Ensuring that the policies and programs which are designed for the management/control of risk from the construction activities consider human limitations.
- Determination to the achieve continuously high construction bench marks which is percolated from the top of the project organization to the bottom through progressive levels;
- Leadership commitment by visible involvement, thereby synergizing efforts at all levels throughout the project organization into productive actions; and
- Creation of a climate in work environment which promotes encourages safety at work.

B. The Work

The project management emphasizes the need for developing human factors in the control of hazards/risks which involve the designing of policies/programs of work to take care of safe human performance. The hazard identification techniques like safety observations, job hazard analysis, safety inspection, risk assessment, etc should be practiced in accordance with ergonomic considerations. The work profiling/ job description/job specifications of every level should be clearly spelled out. The site, human, and technical constraints should be taken into account to reduce human error. The work design includes:

- Identification and critical analysis of significant works at project and assimilation of likely human errors;
- Evaluation of decision-making process and balance between the individual actions and the dynamic work environment.
- Consideration of safety principles to the design of work environment and human –machine interfaces, including safety information.
- Communication of safe work procedures and instructions to all levels.
- Safe design and control of the working environment, including movement space, safe access to heights, ventilation, noise, illumination, hygiene, etc.
- Availability and ensuring/enforcing usage of right tools, machinery, personal protective equipment, etc.
- Planning and scheduling of project activities, including shift work, medical management, fatigue and stress management, preparation for contingencies/emergencies, etc
- Effective and efficacious two / three-way communications at all levels for all times.

C. Human (Individual) Factors

This aspect is concerned with how personal factors such as attitude, motivation, training, human error and the perceptual, physical and mental capabilities of people can interact with health and safety issues.

Attitudes are directly connected with an individual's self-image, the influence of groups and the need to comply with group norms or standards and, to some extent, opinions, including superstitions, like 'All accidents are Acts of God'.

Changing attitudes is difficult. They may be formed through past experience, the level of intelligence of the individual, specific motivation, financial gain, and skills available to an individual. There is no doubt that management example is the strongest of all motivators to bring about attitude change.

Important factors in motivating people to work safely include joint consultation in planning the work organization, the use of working parties or committees to define objectives, attitudes currently held, the system for communication within the organisation and the quality of leadership at all levels. Financially-related motivation schemes, such as safety bonuses, do not necessarily change attitude, people frequently reverting to normal behavior when the bonus scheme finishes.

CONCLUSION

The regulation of construction industry where around 30-40% of the nation's work force are deployed directly or indirectly, has been a challenge. The onus shall be on the mega project management to have a robust safety management system to ensure a safety conscious work environment. The social welfare and safety of the contract workers is still an area where a lot can be done for bettering the lives of many who are temporary workers involved in the nation building programs. The key issue is the consideration of human factors like physical and mental abilities, motivation, safe behavior at work, etc. The strong leadership for safety integrated with commitment, authority, responsibility and accountability should be in place at all levels in the mega projects. The total safety management should be the goal of the construction.

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