International Journal on Engineering Technology and Infrastructure Development (InJET-InDev)
Volume 1, Issue No.1, Page 69-78
Received Date: 12/31/2023
Revised Date: 1/7/2024
Accepted Date: 2/7/2024
ISSN: 3021-999X (Print)

Construction Safety Practice on Pre-stressed Bridge Construction: A Case Study of Parasi District

Krishna Keshab Subedi[1*], Dilman Singh Basnyat[2]

[1]*Engineer, Department of Roads kksubedi2046@gmail.com*
[2] *Secretary, Safe & Sustainable Travel Nepal (SSTN), dilman.basnyat@gmail.com*

Abstract

Prestressed bridge construction is latest technique of bridge construction in Nepal comparison to other techniques. Since these techniques use more mechanical tools and equipment than others; hazards are more. This research assessed the safety in prestressed bridge construction involving stakeholder's perception. The study area is Parasi district of Lumbini province. Seven prestressed bridge sites were selected for the study which included constructed and also the under-construction sites. Primary data was collected by Key informant interview (KII) Survey and field visit whereas secondary data was collected from respective office of client, contractor's office, and Department of Roads (DOR). Multi-stakeholders were identified and KII survey was done for stakeholders with the use of questionnaire prepared. This resulted in account of stakeholders' perception towards availability and supporting of various control measures in site. The research also aimed to analyze the occupational hazards (OHs) with their causes and characterized them considering each of the internal and external factors and assess the preventive and control measures of occupational hazards.

Keywords: pre-stressed Bridge, KII survey, Occupational hazards, Occupational safety.

1.0 INTRODUCTION

Health and safety are crucial requirement in construction of bridge as it is concern with the lives of people. Safety in bridge construction basically concern with the occupational accident and health is concern with occupational diseases or illness. Construction industry records the highest frequency of occupational accident as compared to other industries(Ma Li, 2017).The main causes of most occupational accidents in the bridge construction is largely dependent to poor management and lack of worker safety awareness(Cheng, et al., 2010). Safety at bridge is also crucial and hence is reflected on Road Note 7 too (Tiwari & Luitel, 2023).

In the field of bridge engineering, the introduction of prestressed concrete has aided the construction of long-span concrete bridges. These often comprise precast units, lifted into position and then tensioned against the units already in place, the process being continued until the span is complete. Prestressed bridge construction is latest technique of bridge construction in Nepal comparison to other techniques. Since this technique use more mechanical tools and equipment than others; hazards are more. So, more safety practice is required for construction activities. Occupational health and safety (OSH) aim to prevent injuries and illness in the construction working environment. Thus, this research is conducted to assess safety measures management in Prestressed bridge construction.

2.0 RESEARCH OBJECTIVE

The general objective of the research was to assess construction safety practice on Prestressed Bridge Construction through a case study of Parasi district. The specific objectives were as follows:

- **I.** To identify perceptions of stakeholders towards safety management.
- **II.** To identify the occupational hazards and their causes in pre-stressed bridge construction.
- **III.** To assess precautionary and control measures to be adopted for occupational hazard prevention.

3.0 LITERATURE REVIEW

International labor organization (ILO) recognizes the need for design professionals to be involved and to consider construction safety in their work. Construction industry should implement the concept designing for safety constructability as standard practice to reduce overall hazards in construction. The construction industry has been identified as one of the most hazardous in the United States(US), and occupational falls have been identified as the most common cause of fatal injury(Cattledge, 1996).

Construction sites are generally multiemployer work sites. Safety responsibilities can become decentralized with many contractors and tradesman coming and going. Construction projects are fast moving, which increases the likelihood for hazards to be overlooked. Problems often exist with workers and the work site. All of this adds upto a dangerous environment where incidents are multicausal in nature (Mroszczyk, 2015).

Hazard can be defined as a potential situation that may cause harm, unintentional injuries or deaths to people or damage to, or loss of an item or belongings arises from occupational works(Fang, et al., 2004). It is also known as the counterpart of safety(Fang, et al., 2004). There is good relationship between road crashes and speed (Tiwari, 2015); thus safety aspects of bridge is crucial during construction as well as operation.

Hazards in bridge construction includes dust from the operation of earth moving and grading equipment, gases such as oxides of nitrogen from diesel powered equipment and from blasting, oil mists from spraying, vapors and fumes of asphalt and solvents, dermatitis from contact with cement, lead poisoning from paints etc. In addition to these chemical hazards, workers are exposed to physical agents such as noise from a variety of heavy equipment, extremes of temperature and humidity. Structural steel workers too are subject to hazards other than accidental injuries (Magnuson, July 1961). Bridge fires are low-probability but high-consequence incidents. Generally, bridge design codes and standards, in contrast to building codes, don't consider the concept of fire safety. However, recent high profile fire incidents on bridges and in other infrastructure have opened a debate on the need for fire resistance requirements on bridges (Kodur, 2010).The major hazard in bridge construction is fall hazards from ladders, roof edge and scaffolds (Mroszczyk, 2015).

According to Taiwan, labor safety a major occupational accident is defined as an accident that causes injuries to three or more persons or causes the death of at least one person at the time it occurs(Cheng, et al., 2010). The causes of most occupational accidents in the bridge construction are management negligence and inadequate worker safety awareness(Cheng, et al., 2010).Workplace fatalities and injuries bring great losses to both individuals and societies either by loss life or property. Unsafe acts of people and unsafe condition of workplace are the fundamental reason behind accidents and management is responsible for the prevention of accidents(Fang et al., 2004). Fall or tumble is one of the most common accidents in bridge construction. Failing to implement safety management and training effectively may result in serious occupational accidents. Current site safety management relies mostly on checklist evaluation; however, its effectiveness is limited by the experience and the abilities of the evaluators, which may not consistently achieve the goal of thorough assessment. Recently, several systematic safety risk assessment approaches, such as Fault Tree Analysis (FTA) and Failure Mode and Effect Criticality Analysis (FMECA), have been used to evaluate safety risks at bridge projects (Chen, 2014).

4.0 METHODOLOGY

4.1 Study area

The study area of this research was based on the bridges of the Parasi district, Nepal. Parasi is a district located in Lumbini province of Nepal. It is one of 12 districts of Lumbini.

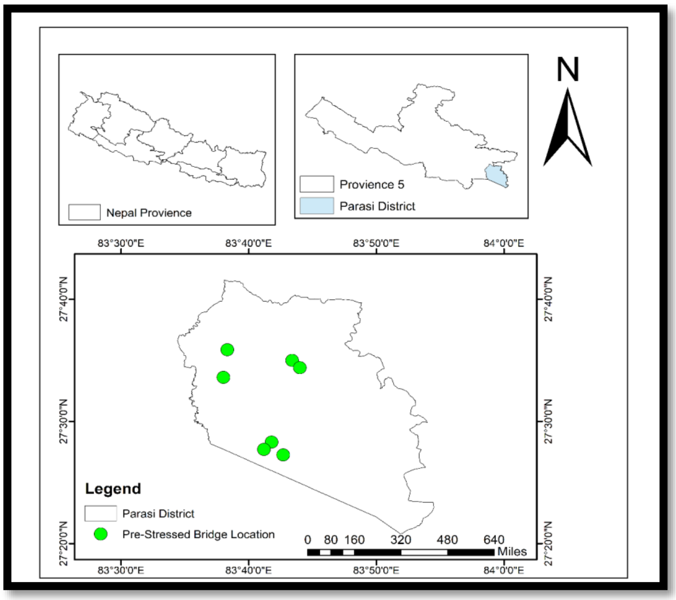

Fig 1. Location of prestressed bridges in Parasi district showing temporal along with administrative details.

Research work only is focused on the projects implemented under DOR, Nepal. That was because of availability of technical data and key information. A total of seven pre-stressed bridges were identified which were under construction or already constructed. The spatially distribution of bridges over the district is presented in the Fig. 1 and Table 1.

Table 1. Name and location of under construction pre-stressed bridge in study area.

S.No	Name of bridge	Location
1	BhaluhiKhola Bridge	Piparahiya ,Nawalparasi
2	BhumahiKhola Bridge	Ramnagar VDC-4,Ghyudall, Nawalparasi
3	JharahiKhola Bridge	Mahespur,, Nawalparasi
4	TuriyaKhola Bridge	Amaraut VDC-03, Nawalparasi
5	TuriyaKhola Bridge	Sunwal Municipality - 3 &10, Nawalparasi
6	BhaluhiNadi Bridge	Tilakpur-5 ,6 & Ramnagar-7, MisrauliSadak, Nawalparasi
7	KhajuraKhola Bridge	Darkhase , NawalParasi

.

4.2 Data collection

In order to design bridge safety perception, it was necessary to gather information from parties who were responsible for it the most. Both perceptible and imperceptible stakeholder was brought under investigation of safety consideration. Secondary data was collected from the respective offices of the client and the contractor. Basically, contract documents and daily/monthly reports were used for drawing secondary data. Also, technical drawings and reports were also used to extract the missing Secondary data. Similarly, other secondary data and information were taken from similar studies done in other countries. Primary data were collected by field visit and key informant interview (KII) survey of the personnel related to the study. The data were further analyzed after such survey in all sites and processed using statistical method. Key informant interview (KII) was conducted with the experts of prestressed bridge construction. Following are the representative for KII:

Client	Project Manager/ Site Engineer
Contractor	Project Manager/ Site Engineer/Workers

After completing all questionnaire survey with respective stakeholder, then all obtained data were tabulated in standard from for preventative model development. Numerical type, logical type, character type and string data were sorted out for next analysis. Also, data was analyzed according to mode of construction of pre-stressed bridge. Field observation was used as one of the data collection mode. So it was used to identify different occupational hazards, preventive and control measures at bridge construction. Field observation was also conducted with the help of questionnaire.

4.3 Study population and sampling

This approach is to use the entire population as the sample. Although cost considerations make this impossible for large populations, a census is attractive for small populations (e.g., 200 or less). A census eliminates sampling error and provides data on all the individuals in the population (Israel, 1992). Selection of sample was based on random probability sampling. The results obtained from random sampling can be assured in terms of degree of randomness (entropy) i.e., we can measure the errors of estimation or the significance of results obtained from a random sample, and this fact brings out the superiority of random sampling design over the deliberate sampling design. Cochran's formula for calculating sample size when population size is finite

$$\boldsymbol{n} = \frac{\boldsymbol{n_0}}{1+\frac{(\boldsymbol{n_0}-1)}{\boldsymbol{N}}} \qquad \text{Eq. (1)}$$

Where n is the sample size; N is the population size.; n_0 is calculated sample size for finite population
Therefore, number of sample was taken 35 stakeholders out of total population size of 38.

5.0 RESULTS AND DISCUSSION

Seven prestressed bridges supervised by division of roads in Parasi district were analysed in this research. At least five in each site available and most important stakeholders were selected by sample analysis and priorities were set using local wisdom and cluster sampling techniques. The primary and secondary data of this research assessment gave the vital output based on the approved and verified tactical calculation. Analysis from primary and secondary data for the pre-stressed bridge cleared the perceptions towards hazards and risks, types of occupational hazards during construction, and most importantly the preventative and control measures to be adopted in site.

5.1 Perceptions of stakeholders towards safety management.

All possible and available stakeholders were accounted in the research work in order to get perceptions, knowledge, understanding, critical thinking, implementation and all safety related association. Each site had multiple stakeholders and out of these stakeholders, vital five (workers, contractor, consultant foreman and local people) participated in the survey works enthusiastically and willingly. Assuming that their statements were valid and logical in drilling regards, the finds found to be interesting based on the statistics and overall trend analysis.

Table 2 Stakeholders perception towards availability and supporting of various control measures in site (Frequency based).

S.N	Control Measures	Not at All	Very less	Occasionally	Often	Regularly
1	Elimination (%)	0	71.43	22.86	5.71	0
2	Replacement or Substitutions (%)	0	2.86	82.86	8.57	5.71
3	Engineering Control (%)	0	0	57.14	31.43	11.43
4	Administrative Control (%)	0	14.29	22.86	48.57	14.29
5	Personal Protective Equipment (%)	0	6.45	58.06	35.48	12.90

As represented in Table 2, after completion of the survey of multiple stakeholders, the perception was identified towards various control measures in the site according to frequency based. Nearly, 71% of the participants said the very less chances of elimination of the structure whereas, 22% said occasionally elimination and only 5.7% said often elimination.

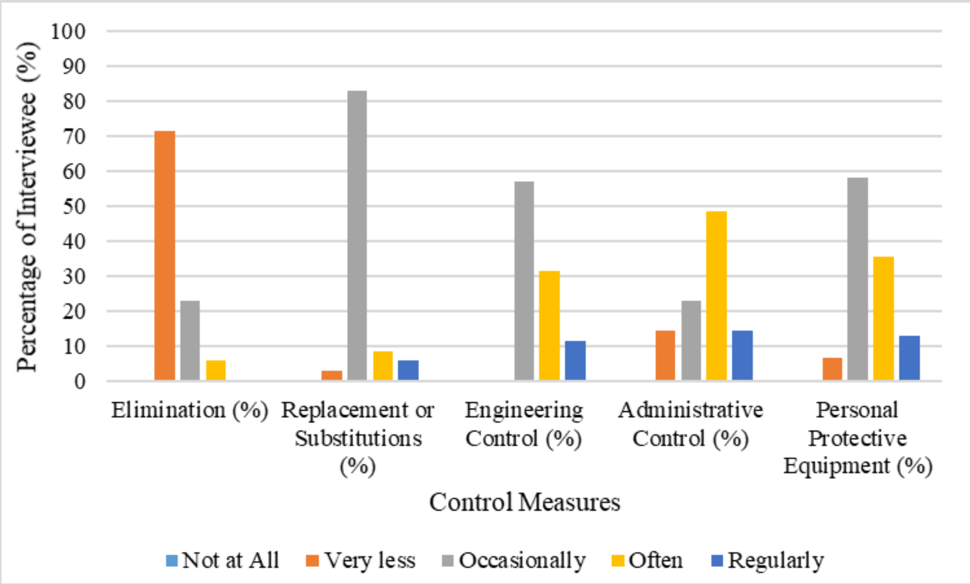

Fig. 2 Identification of control measures based on the perception of stakeholders.

In case of substitutions, the 82.86 % participants said occasionally substitution of damaged material. Only one participants said complete replacement of that materials and also five (5) people said often and regular replacement of the damaged part. For engineering control, 57.14% participants said occasional and 31.43 % and 11.43% participants respectively said often and regularly. For administrative control, majority (48.57%) said often and for personal protective equipment (PPE), majority (58.06 %) said occasional.

5.2 Assessment of occupational hazards and their causes in prestressed bridge construction.

5.2.1 Interpretation of yes/no questions

The interpretation of yes/no question was performed by logical data analysis. In terms of yes/no question there was random variation of answers among multiple stakeholders. Every answers were brought together and were summarized. The details are presented in Table 3. And Fig 3

Table 3. Answer to yes/no questions.

S.N	Description	Yes	No
1	Company safety plan(%)	8.57	91.43
2	Safety equipment's(%)	20.00	80.00
3	Trainings for tools and machines(%)	14.29	85.71
4	First aid kit availability(%)	97.14	2.86
5	Fire extinguisher availability(%)	5.71	94.29
6	Insurance policy(%)	100.00	0
7	Implementation of safety program(%)	5.71	94.29
8	Works delayed due to accidents/s(%)	94.29	5.71
9	Treatment by company who has suffered accident(%)	97.14	2.86
10	Legal charges due to unsafe construction practice(%)	0	100.00

The majority of the survey participants gave a "yes" as a response for availability of safety equipment, trainings for tools, first aid kit availability, insurance policy and no on legal charges due to unsafe construction practice.

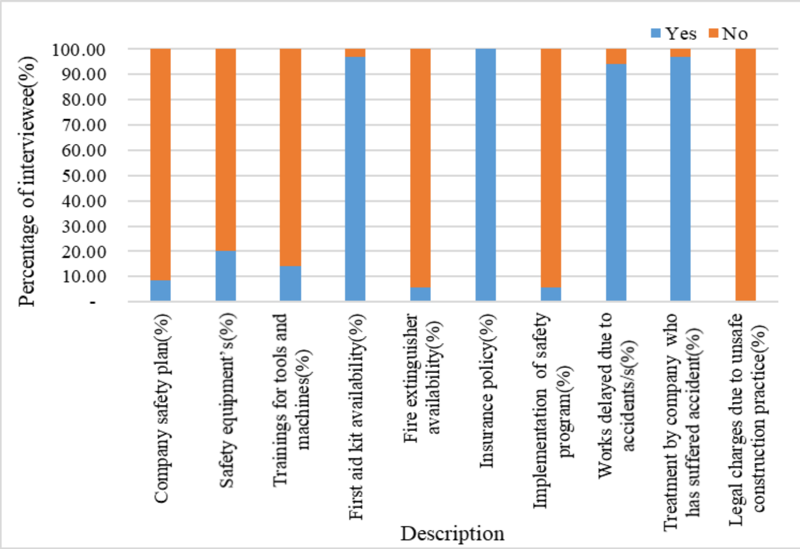

Fig. 3 Yes/No questions responded by stakeholders upon different triggering agent of occupational hazards.

From Fig. 3 and Table 3, it can be easily interpreted that there has been a construction safety plan but not much implementation has been carried out in field. Same seemed to be the case for safety equipment. Approximately 86% of interviewee suggested that Inspite of availability of tools and machines there is not proper provision of trainings for the tools. Besides that, approximately 94% of interviewee pointed out the unavailability of fire extinguisher in the site. This can be the cause of several fire related accidents and the impact could go really long way.

No interviewee advocated for the insurance policy, since all the sites had one for the workers. Although there was proper safety program in each sites, most of the interviewee said that there was no proper implementation in actual site. Also, due to occurrence of accidents, work is delayed in respective sites. This might be due to lack of proper management in site and lack of safety plan implementation.

Majority (97% approx.) suggested that the treatment of the works who had an injury in site was done by company itself whereas remaining 3% suggested they had to take the expenses on their own. Besides that, no legal charges were made on any of the site on charge of unsafe construction practice as per the interviewees.

5.2.2 Causes of occupational hazards in prestressed bridge construction

The main possible causes for the occupational hazard in sites were studied and compiled together in the questionnaire. Together other possible causes (that may be site specific) were asked with the interviewee. The list of causes generated string data and hence forth string analysis was carried out for obtaining this objective.

In order to identify the most sensitive hazard parameters in pre-stressed bridge construction the most effective and wide accepted ranking method was adopted. After successfully completion of multiple stakeholder's survey, the parameters ranking was done in the basis of percentage of satisfactory or willingness degree. The cause which was pointed out by most of the interviewees was ranked as most sensitive followed by the cause with less preference by interviewee. The causes of occupational hazard in prestressed bridge construction are presented in Table 6 in rank of sensitivity.

Table 4 Occupational hazard and its causes in pre-stressed bridge construction and its matrix (Sensitive wise).

S.N	Causes	Hazards
1	Improper distribution of work among random workers	Fall from height
2	Inadequate PPE in sites	Electrical shocks
3	Lack of training	Tools and equipment's
4	Poor workmanship	Machine related incident

S.N	Causes	Hazards
5	Absence of proper machine operation and regulation enhancement	Tools and equipment's
6	Lack of policies and guidelines (safety plan)	Overall hazard
7	Inadequate safety training to workers	Overall hazard
8	Lack of monitoring	Severe accident
9	Unavailability of design of safety plan	Severe accident

The hazard with the most sensitivity was identified as fall from height due to distribution of work among random workers but each worker is not specified for each tasks separately. That is followed by electrical shocks due to unavailability of PPE in sites, hazards due to misuse of tools and equipment that seemed to be result of lack of workmanship and negligence in machine operation and regulation. Then, there are overall hazards due to inefficient safety plans, lack of monitoring and unavailability of design of safety plan.

5.3 Assessment of preventive and control measures.

5.3.1 Improvement of occupational health and safety.

Risk mitigation is an integral effort in construction and its success requires inputs from all stakeholders including owners, designers, builders, and suppliers (Floyd and Liggett, 2010). Such effort is difficult due to a construction project's fragmented nature with a variety of stakeholders across phases from design to construction (McCoy et al., 2009). Stakeholders in the construction phase are often targeted as the sole administrators for safety measures and implementation (Toole, 2002). For example, in the U.S., design professionals are not responsible for specifying means and methods of construction while the contractors need to take full responsibility to substantial safety risks on the jobsites.

Safety management is a very important criterion for any organization's smooth functioning. If a workplace is run, employees should be ensured to be safe from all kinds of occupational hazards at all times. An employee can be exposed to many different types of occupational hazards every day. So as an organization, it is needed to ensure that the workplace is hazard-free by following a certain set of standard rules and regulations.

There were at least eight (8) parameters to further enhance the insights to safety plan. From Table 5 and Fig. 4 , it can be seen that how distributions of perceptions have been taken place. Mostly, the parameters which this study focused were strongly agreed by stakeholders. Due to lack of safety plan at site, most of the hazard have taken place so 57% stakeholders have strongly agreed to design the pre-safety plan. Also, frequently monitoring of site by safety experts also found to be lack and it was extremely necessary. Moreover, the required training for construction workers is necessary in order to reduce such hazards. Classifications of workers in thematic ways, machine operation division and addition of PPE in sites were the other major parameters which the stakeholders have strongly agreed

Table 5 . Improvement of occupational health and safety.

S.N	**Techniques**	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
1	Redesign of safety plan (%)	0	0	14.29	74.29	11.43
2	Frequent monitoring (%)	0	2.86	25.71	54.29	17.14
3	Addition of training (%)	0	0	2.86	14.29	82.86
4	Addition of PPE (%)	0	0	0	11.43	88.57
5	Safety training to workers (%)	0	0	11.43	42.86	45.71
6	Machine operation and regulation enhancement (%)	0	0	5.71	17.14	77.14
7	Policies and guidelines (safety plan) (%)	0	0	14.29	28.57	57.14

8	Workmanship(%)	0	0	14.29	2.86	82.86
9	Classification of works among workers (%)	0	0	0	2.86	97.14

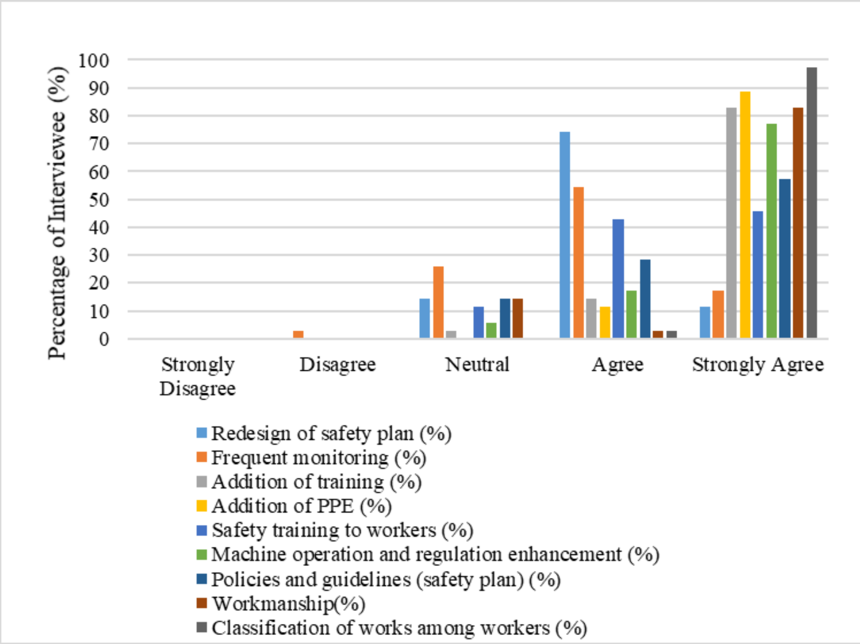

Fig. 4 Techniques to reduce hazards based on the perception of stakeholders.

As represented in Fig. 4 and Table 5, for reduction of hazards, according to perception of stakeholders, majority strongly agree on addition of training, addition of PPE, regular enhancement of machine operation, workmanship and classification of works among the workers.

5.3.2 Ranking matrix and intensities of remedies.

The percentage of viewpoints was calculated upon participant's perceptions towards strongly agreed to total number of participation of stakeholders. In terms of degree of view, the results were classified as low (0-40) %, medium (40-70) % and high (70-100) % on the basis of response of participants. The highest percentage of interviewee (85%) focused on proper classification of works among workers as the main remedial technique for occupational hazard. It was then followed by addition of PPE with 77.5% of interviewee's viewpoint. Then, with 72.5 % of interviewee's opinion was both addition of training and proper workmanship. All these four measures had the percentage of above 70%, hence were categorized under high intensity measures. Then with the interviewee's response in range of (40-70) % were the remedies; machine operation and regulation enhancement, policies and guidelines and safety training to workers successively. At last with least of the interviewee's viewpoints were frequent monitoring (15%) and redesign of safety plan (10%).

Table 6 Ranking matrix of occupational hazard and corresponding remedies techniques to reduce such hazards (percentage chronological order).

S.N	Methods/Techniques	Percentage of viewpoints	Remarks
-1	Classification of works among workers	85	High
2	Addition of PPE	77.5	High
3	Addition of training	72.5	High
4	Workmanship	72.5	High
5	Machine operation and regulation enhancement	67.5	Medium
6	Policies and guidelines (safety plan)	50	Medium

7	Safety training to workers	40	Medium
8	Frequent monitoring	15	Low
9	Redesign of safety plan	10	Low

Classification among workers, addition of PPE, trainings and skilled workmanship were found to be most sensitive which means need to be addressed. And redesign of safety plan and frequent monitoring were found to be less sensitive which have not significant role in control measures.

The remedy which was voted as most important was the specific work division among the workers according to their qualification and skills. Then, there is addition of PPEs for prevention of electric shocks and other physical hazards. Similarly, in this order training to be provided for each worker according to their allocated tasks seemed necessary. Improvement of workmanship and following that machine operation and regulation was considered another necessary steps for controlling occupational hazard. Following that are safety plans implementation, frequent monitoring and redesign of safety plan simultaneously as per their rank in the ranking matrix.

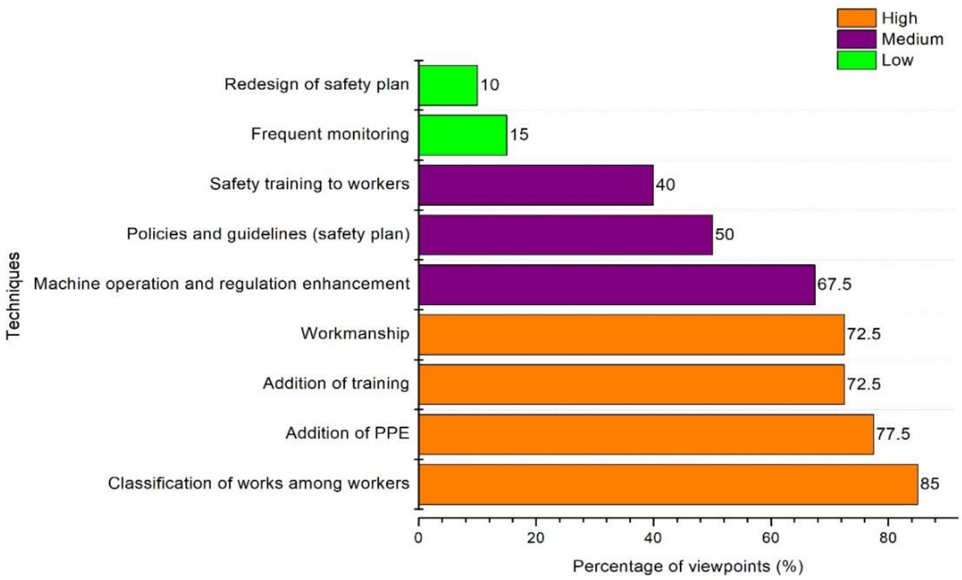

Fig. 5 Distribution of sensation of techniques in order to reduce occupational hazard.

Fig.5 shows the distribution of importance of each nine techniques for reduction of occupational hazards. First four; (Classification of works among workers, addition of PPE, addition of training and workmanship) were ranked as techniques with high importance among nine techniques. It was followed by three; (Machine operation and regulation enhancement, policies and guidelines and safety training to workers) as medium importance techniques and further 2; (frequent monitoring and redesign of safety plan) least important techniques as per the participants' response. Hence, for safety in site, priorities need to be set based on this importance list as they have significant impact on the occupational hazards.

6.0 CONCLUSION

The research identified the perception of multi-stakeholders towards availability and supporting of various control measures in prestressed bridge sites. The research identified occupational hazards in sites, which includes fall from bridges during construction, electrical shocks, hazards related to tools and equipment's, machine related incident. Additionally, the research assess the preventive and control measures addressing all the identified causes. This identified perception as well as causes helps the construction manager to ensure safety during construction works on sites of prestressed bridges.

7.0 ACKNOWLEDGEMENT

The authors would like to acknowledge the significant input received from Er. Hemant Tiwari during data collection, literature review, analysis and research paper preparation phase.

REFERENCES

Abdelhamid, T. S. (2000). IDENTIFYING ROOT CAUSES OF CONSTRUCTION ACCIDENTS. *JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT*.

C., C. (2010). Characteristic analysis of occupa-tional accidents at small construction enterprises. *Safety Science*.

Chen, T.-T. (2014). Fall risk assessment of cantilever bridge projects using Bayesian network. *Safety Science*.

DoR. (2020). *Prestressed bridge in Nawalparasi.* Butwal: Department of Road.

Falyo, D., & Holland, B. (2017). Medical and psychosocial aspects of chronic illness and disability. *Jones & Bartlett Learning.*

Gautam, R. a. (2012). Decent and sustainable green jobs in Nepal. *GEFONT publication*.

Hewson, N. R. (2003). *Prestressed concrete bridges design and construction.* Thomas telford pulishing, thomas telford ltd.

International Labour Organigation (ILO), 2. I. (2009). ILO standards on occupational safety and health.

Israel, G. D. (1992). Determining Sample Size.

Kodur, V. (2010). Review and Assessment of Fire Hazard. *Journal of the Transportation Research Board,*.

Magnuson, H. J. (July 1961). Health hazards in construction industry. *Journal of occupational medicine*.

Meng-shu, W. (2008). Analysis of Accident Induced by Urban Underground Project Construction and Its Control Measures. *Journal of Architecture and Civil Engineering* .

Mroszczyk, J. W. (2015). Improving Construction Safety. *ProfessionalSafety*.

Shrestha, S. (2019). Perception on Safety in Nepalese Construction Industry. *Journal of Structural Engineering, Its Application and Analysis, 2*(2), 1-5.

Shrestha, S., & Shrestha, H. M. (2019). Construction Safety Measures Implementation Status in Nepal. *Journal of Advances in Civil Engineering and Management*, *2*(1), 1-4.

Skyler, J., Bakris, G., Bonifacio, E., Darsow, T., Eckel, R., & Groop, L. (2017). Differentiation of diabetes by pathophysiology, natural history, and prognosis. *Diabetes.*

Ti, X. (2013). *Analysis and Risk Control and Management of Accidents that Scaffold Collapses in Building Construction.* Beijing: China Aviation International .

Tiwari , H., & Luitel, S. (2023). Re-orienting towards Safer Roads Infrastructure in Nepal. *Journal of Recent Activities* , 14-27.

Tiwari, H. (2015). Dependency of Road Accidents with Volume and Speed (A Case Study of Major Black Spot Location within Kathmandu Valley). *Proceedings of IOE Graduate Conference*, (pp. 339-343).