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Ergonomic working posture analysis on highway construction work using the OWAS method

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Abstract

Road construction work has a high risk of injury due to non-ergonomic work postures, such as hunched and twisted postures. Such injuries negatively impact workers' health and can also lead to decreased productivity, higher medical costs, and delayed project completion. This study is important to conduct because of the lack of attention to ergonomics in the construction sector, especially in Indonesia, which results in an increased risk of work accidents and musculoskeletal injuries. Using the Ovako Working Posture Analysis System (OWAS), this study aims to analyze work postures in various road construction activities and identify work positions that have the potential to cause injury. The results of OWAS observations and analysis show that several main jobs, such as road construction (AC 4 = 63.6%), asphalt leveling with screws (AC 4 = 78.6%), and narrow side casting (AC 3 = 21.4%; AC 4 = 42.9%), have a high risk of poor posture. This study suggests ergonomic interventions such as posture training and the use of heavy equipment to reduce the risk of injury and improve work efficiency. The conclusion of this study is expected to provide an overview of the postural distribution of road construction workers, as well as identify the riskiest work postures, so that effective recommendations can be proposed to improve work safety and productivity.

Keywords:
Construction, ergonomics, OWAS, working posture, work injury.

1 Introduction

The development of road infrastructure plays an important role in the progress and development of a country. However, the highway building process involves construction work that requires workers to carry out heavy physical tasks and high risks. A high risk of injury and fatigue can occur in highway construction workers due to non-ergonomic work postures.

This problem triggers the need for an ergonomic analysis to determine a safer and more effective working posture for workers. Several previous studies have been carried out to discuss the principles of ergonomics in construction work and the methods used to analyze work postures and body movements of workers.

One method that is often used in ergonomic analysis is the Ovako Working Posture Analysis System (OWAS) method. This method is used to analyze workers' work posture and body movements, as well as assess the risk of injury and fatigue in workers. Several previous studies have used the OWAS method to analyze the work posture of construction workers at project sites.

For example, a study conducted by Tzu-Hsien Lee & Chia-Shan Han (2013), discussed the analysis of work posture in construction workers in Taiwan using the OWAS method. This research found that there are several work postures that are not ergonomic in construction workers, such as hunched posture and hunched posture. This can increase the risk of injury and fatigue in construction workers.

Based on this background, the aim of this research is to analyze the work posture and body movements of highway construction workers using the OWAS method, as well as provide recommendations for preventive actions that can be taken to reduce the risk of injury and fatigue in workers. In this research, observations were made of 2 highway construction workers who were carrying out work on a highway construction project.

The data taken includes work posture and body movements of workers using the OWAS method. Apart from that, data was also collected on worker characteristics such as age, gender, and work experience. The data was analyzed using a special computer program to calculate the OWAS index number and determine workers' non-ergonomic working postures.

The results of data analysis are expected to provide useful information for construction companies to make improvements and improve working conditions for highway construction workers. Thus, it is hoped that this research can make a positive contribution to the development of ergonomics and work safety in the highway construction industry.

2 Research Methods

This study uses the Ovako Working Posture Analysis System (OWAS) method, an ergonomic analysis technique that aims to evaluate the working posture of highway construction workers during physical activities in the field. OWAS is used to identify and classify workers' body postures based on different injury risk categories. This study will involve direct observation of several construction workers participating in a highway construction project. The collected work posture data will be analyzed using a calculation table designed to calculate the OWAS index, which will be used to identify non-ergonomic work postures that have the potential to cause injury. Thus, this approach will provide a comprehensive picture of the workers' working posture conditions, as well as the associated injury risks, so that preventive measures can be proposed to minimize the risk of fatigue and injury.

Several previous studies have been conducted to discuss the principles of ergonomics in construction work and the methods used to analyze workers' work postures and body movements.

2.1 Ergonomics in Construction Work

Construction work, especially in highway construction, involves intense physical activity with high workloads. Ergonomic studies on the work environment in the construction sector aim to minimize the risk of Musculoskeletal Disorders (MSDs) in workers which are often caused by improper posture, repetitive movements, and heavy physical loads. Research by Ghasemkhani et al. (2008) stated that musculoskeletal complaints are one of the common problems in the construction sector, where non-ergonomic work postures are one of the main factors. This study highlights the importance of analyzing work postures in the field to identify potential risks that can cause injury to workers.

2.2 Ovako Working Posture Analysis System (OWAS) Method

The OWAS method was first developed by Karhu et al. (1977) to identify and classify risky work postures, especially in heavy industry. OWAS is used to observe and evaluate workers' body postures based on the position of the back, hands, feet, and the load being lifted. Karhu et al. (1981) in their study stated that OWAS is effective in identifying dangerous body postures and provides recommendations for improvement. This method divides posture risks into four Action Categories (AC) indicating the level of urgency of posture change: from not dangerous (AC1) to very dangerous (AC4), where corrective action must be taken immediately.

The OWAS method has been widely applied in various types of work, including the construction industry. Tzu-Hsien Lee & Chia- Shan Han (2013) in their study used OWAS to assess work postures in the construction sector and found that the majority of workers had non-ergonomic postures, with varying degrees of severity depending on the task being performed. Postures that were frequently detected involved hunched backs and bent legs, which significantly increased the risk of injury. These findings are relevant in the context of research on highway construction workers, where similar work postures can be found.

2.3 Relevance of OWAS Method to Work Highway Construction

In highway construction work, as with other construction sector work, workers are often exposed to conditions that force them to work in poor posture for long periods of time. Bending, twisting, and lifting postures are typical of work in this sector, especially in activities such as asphalt leveling, lifting materials, and other manual work. Suparlan & Tamrin (2012) showed that poor working posture in highway construction work can cause lower back injuries, shoulder injuries, and excessive physical fatigue.

This study also underlines the importance of identifying high-risk postures so that appropriate preventive measures can be taken.

2.4 Comparison with Posture Analysis Method Others (RULA, REBA, QEC)

In addition to OWAS, there are several other methods commonly used to analyze work postures, including Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), and Quick Exposure Check (QEC). Each method has a different approach in measuring ergonomic risks in workers.

RULA is used to evaluate ergonomic risks, especially in the upper limbs. This method is more suitable for work that requires manual precision or static activity. Involving upper body posture (McAtamney & Corlett, 1993), RULA is often used in jobs involving typing, surgery, or sedentary manufacturing.

REBA provides a more comprehensive evaluation of the entire body, including the posture of the neck, trunk, arms, and legs. REBA is suitable for jobs with dynamic postures that involve the entire body. Hignett & McAtamney (2000) stated that REBA is often used in posture analysis involving manual handling or lifting activities.

QEC is a quicker method for assessing exposure to non-ergonomic postures, where workers are invited to provide feedback on their own work, thus there is a high element of subjectivity. David et al. (2008) emphasize that QEC is particularly useful in jobs involving repetitive movements or high physical loads.

Based on a literature study, the OWAS method is more appropriate to be used in this study because OWAS identifies risky postures in the main body positions (back, hands, feet), which include the general characteristics of highway construction work. This method also provides clear action categories, which can be used as a basis for providing appropriate recommendations for posture improvement.

The selection of the method discussion using the Ovako Working Posture Analysis System (OWAS) is based on several strong reasons, both in terms of method excellence and relevance to the research context of highway construction work. Here are some of the main reasons why OWAS was chosen:

1. Suitable for work posture analysis in the construction environment

Construction work, especially in highway construction, involves repetitive physical activity and carries a high risk of poor posture.

The OWAS method is particularly appropriate because it is specifically designed to assess work postures in a variety of environments, such as the manufacturing and construction industries. OWAS allows for direct analysis of a variety of body postures, including bending, twisting, and lifting, which are common in highway construction workers. OWAS is able to categorize the risk of injury due to non-ergonomic postures quickly and accurately, making it a suitable choice for dynamic environments such as construction.

2. Systematic and easy to use in the field

OWAS is a simple and easy-to-apply method for field observations. Researchers can directly observe the postures of workers and record them based on categories set by the OWAS system. Each work posture is given a risk classification, from low to very high risk (AC 1 to AC 4), which makes it easier for researchers to understand the level of danger of the posture. The simple OWAS classification system also helps in identifying work whose postures require immediate improvement, so that interventions or recommendations can be given appropriately.

3. Identifying postures that are harmful to health

OWAS has been proven to be an effective method in identifying work postures that are harmful to workers' health. In this study, postures such as bending, twisting, or lifting excessive loads can be evaluated specifically, so that it can be known which postures are most at risk of causing injury or fatigue in highway construction workers. This is very relevant because construction work often involves unnatural postures and must be done for a long time.

4. Providing practical and applicable solutions

In addition to analyzing postures, OWAS also provides recommendations for actions based on the identified risk levels. Each posture categorized into a certain risk level (AC 3 or AC 4) usually requires corrective action, be it posture correction, modification of work tools, or changes in work methods. This is very important for this study which aims to provide practical recommendations for workers and construction companies in reducing the risk of injury.

5. Supporting ergonomic evaluation and improvement in construction environments

By using OWAS, researchers can provide a more comprehensive picture of ergonomic conditions at construction sites. This method helps in evaluating whether the posture and body movements of workers are in accordance with ergonomic principles, and provides recommendations for improvement. In addition, OWAS allows for the analysis of various postures that occur during different types of work, such as paving, casting, or the use of manual tools, all of which require good ergonomic supervision.

6. Immediate action recommendations

One of the advantages of OWAS is its ability to generate action recommendations based on the severity of the risks identified during the observation. For example, if the work posture falls into the action category AC 3 or AC 4 (high risk level), then the study can immediately recommend corrective steps that must be taken immediately, such as repairing work tools or providing ergonomic training to workers.

7. Scientifically proven uses

The OWAS method has been widely used in scientific research and has proven to be a reliable tool for analyzing work postures in various industries. In previous studies, OWAS has been shown to provide valid results and can be applied in real work situations, such as in the construction industry. The reputation and validity of OWAS in the context of ergonomics research are some of the main reasons why this method was chosen for this study. Related research in road construction work *raya*.

Ergonomic studies in the highway construction sector are still limited, but several studies have underlined the importance of ergonomic analysis in this field. Punnett & Wegman (2004) revealed that workers in the highway construction sector often experience physical complaints related to non-ergonomic working postures, such as back pain, shoulder pain, and other musculoskeletal disorders. Yusoff et al. (2015) in their study found that highway workers are more susceptible to physical injuries due to uncontrolled working environments, poor working positions, and lack of ergonomic aids.

This study shows the importance of preventive measures through more ergonomic job design and the use of technology that supports better work postures.

2.5 Recommendations for Further Research

Previous studies have highlighted the importance of identifying risky work postures and mitigating measures that can be taken to improve worker health and safety.

By applying the OWAS method to highway construction workers, it is hoped that the riskiest work posture patterns can be found, which are: then can be used as a basis for formulating recommendations for improvement. The use of heavy equipment, ergonomic training for workers, and changes in job design are some of the recommendations that may be taken based on the results of this study.

By conducting a literature review covering the OWAS method, previous research on work postures in construction, and comparisons with other methods, this study is expected to provide important contributions to improving work safety in the highway construction sector. The results of the analysis are expected to provide deeper insight into the riskiest work postures and the steps that need to be taken to minimize injuries to construction workers.

Based on the background, the purpose of this study was to analyze the working posture and body movements of highway construction workers using the OWAS method, and to provide recommendations for preventive measures that can be taken to reduce the risk of injury and fatigue in workers. In this study, observations were made of 2 highway construction workers who were working on a highway construction project.

This study uses a quantitative descriptive method with an observational approach. This method is used to analyze and interpret the working posture data of highway construction workers with the aim of providing an overview of risky postures and necessary preventive measures. To conduct the ergonomic analysis, the Ovako Working Posture Analysis System (OWAS) method is used, which is a standard tool for assessing the risk of non-ergonomic working postures.

2.5.1 Observational Approach

This study is observational, where direct observation is conducted on construction workers involved in various activities at the highway construction site. Researchers observe and record the posture of workers during the activities carried out, such as bending, twisting the body, lifting weights, and other positions that have the potential to cause injury or fatigue.

2.5.2 Population and Sample

The population in this study were construction workers involved in highway construction projects. The sample was taken purposively, namely workers who do work with a high risk of poor work posture. In this case, the study was conducted on 12 workers for detailed observation in the field.

Observations were only conducted on 12 workers because the approach used in this study was a purposive sampling approach. This means that the workers selected are individuals who have special characteristics or carry out work that is relevant to the study, especially work with a risk of work posture that is considered high. Purposive sampling is a sampling method that selects respondents intentionally based on certain considerations, such as work that often causes injuries due to non-ergonomic postures. This ensures that the study focuses on workers with the highest risk and work postures that most often cause health problems.

Reasons for using a sample of 12 workers:

1. Job relevance

   The 12 workers were selected based on their job relevance to tasks that require certain risky work postures. For example, they perform heavy work involving bending, twisting, lifting, etc.

2. Specificity and focus

   Since the main objective of this study was to evaluate work postures in highway construction work that has a high risk of injury, the number of 12 workers was considered representative enough to see the variation and frequency of risky postures.

   Intensive observation of this small but relevant sample provides more in-depth results about the ergonomic conditions in the field.

3. Case study or exploratory research

   This research can be categorized as exploratory descriptive research, where a smaller sample size is acceptable to explore in depth the phenomenon or condition being studied. Exploratory descriptive research is often used to better understand problems that are relatively complex or that have not been studied in depth in a particular context, such as the ergonomics of highway construction workers.

   In this context, exploratory descriptive research allows for in-depth observation of each worker involved, resulting in a clearer picture of the risky postures.

4. Resource limitations

   Small sample studies are also often conducted due to resource limitations, such as time, budget, and research personnel. However, even though it was only conducted on 12 workers, the quality of the data produced remained high because observations were made in detail and directly in the field.

5. Types of research

   By using small samples and purposive sampling, this study is included in the category of exploratory descriptive research. This type of research is used to describe conditions that occur in depth with the aim of understanding phenomena that have not been widely explored or to provide a more detailed understanding of a problem. In this case, the study aims to describe the working posture of highway construction workers who are at risk of injury based on direct observation.

2.5.3 Data Collection

Data were collected through direct observation in the field using the OWAS method, where each identified work posture was recorded based on the OWAS categorization. This category refers to the posture of the body, arms, legs, and strength used by workers during work.

Each posture is classified into a certain category based on the level of risk they pose, namely category 1 (safe posture) to 4 (very dangerous posture and requires immediate corrective action).

2.5.4 Ergonomic Analysis Tool (OWAS)

The OWAS method is used as the main tool to evaluate workers' work postures. Each observed posture is placed in a certain category based on its level of risk to health.

The OWAS system separates body postures into several combinations, such as back posture (upright, bent, twisted), arm posture, leg posture (standing, kneeling, or squatting), and the force or load lifted by the worker. Based on this analysis, researchers can determine the level of action to be taken to reduce the risk of injury.

2.5.5 Statistical Analysis

Data obtained from work posture observations were analyzed quantitatively using statistical software. In this case, OWAS results were analyzed by measuring the percentage frequency of each work posture that fell into the risk category.

Each posture is classified into Action Category (AC):

1. AC 1: posture is safe and requires no corrective action.

2. AC 2: posture that requires attention, but does not require immediate correction.
3. AC 3: poor posture and needs to be corrected as soon as possible.
4. AC 4: very poor posture and requires immediate action to prevent injury.

In addition, the data were analyzed using descriptive statistical methods to describe the frequency distribution of risky work postures. The main indicators calculated include the percentage of dangerous postures, the average frequency of occurrence of non-ergonomic postures, and the standard deviation of the observation results.

Observations were conducted using a direct observational approach at the highway construction project site. Researchers participated in workers' daily activities to gain a better understanding of the working conditions and postures used. In this observation, researchers used a checklist that included various working postures and body movements relevant to the analysis.

The duration of observation conducted in this study was two weeks, with a total observation time of approximately 40 hours. During this period, researchers observed two highway construction workers. Observations were divided into sessions, where each session lasted between 1 and 2 hours. Researchers recorded the workers' work postures and body movements in real time for further analysis.

1. Preparation

Before the observation, the researcher held a discussion with the project manager to understand the activities to be observed and obtain permission to conduct the observation.

2. Observation implementation

Researchers record the work postures used by workers during each session. Visual aids such as photos or videos can be used to document non-ergonomic body positions.

3. Post-observation interviews

After the observations were completed, the researcher conducted brief interviews with the workers to gain a deeper understanding of their experiences, including duration and the impact of non-ergonomic positions experienced during work.

Data collected through observation and interviews were then analyzed using the OWAS method to determine the level of risk and provide recommendations for ergonomic improvements. The results of this analysis are expected to provide meaningful insights for project management and workers about the importance of safe working postures.

2.5.6 Conclusion and Recommendations

Based on the results of statistical analysis of OWAS data, researchers will conclude that the most risky work postures among highway construction workers. These conclusions will be used to provide recommendations for preventive measures, such as the use of assistive devices, correct posture training, or changes to safer and more ergonomic work methods.

With this method, the research is expected to provide valid and measurable results regarding the risks of work postures and recommendations for appropriate actions to reduce the risk of injury to highway construction workers.

The explanation of the Ovako Working Posture Analysis System (OWAS) process in evaluating workers' working posture are:

1. Observe the worker's posture

First of all, the worker's work and work posture are observed by the researcher. Researcher should pay attention to the worker's body position when performing certain tasks, for example, standing, sitting, bending, or lifting weights. Researcher should also pay attention to other factors such as task duration, strength demands, frequency of movement, and work position.

2. Get the OWAS score in the table

After observing the worker's posture, the researcher assigns a score to the worker's body position. The OWAS score is obtained by referring to Table 1 of the OWAS assessment which contains pictures of working postures and corresponding values. Score values are given for three different parts of the body, namely the upper arm, lower arm and neck. The OWAS scores for each body part are added up to produce a total score.

3. Get the OWAS class in the next table

After getting the total score, the researcher uses the next table to determine the appropriate OWAS class. This table contains a combination of upper and lower arm OWAS scores. The OWAS class indicates the critical level of the worker's body then corrective action must be taken to reduce the risk of injury and health complaints. Evaluation of workers' body position and implementation of corrective actions must be carried out continuously to ensure safe and healthy working conditions for workers.

Table 1 : Definition of Postural Codes in Ovako Working Posture Analysis System (OWAS)

Posture			
Trunks	Arm	Legs	Force(kg)
1 = straight/upright	1 = both arms below shoulder height	1 = sitting	1 = < 10
2 = bent forward	2 = one arm above shoulder height	2 = standing on both legs straight	2 = 10 - 20
3 = straight and twisted	3 = both arms above shoulder height	3 = standing on one straight leg	3 = > 20
4 = twisted bend		4 = standing on both legs bent	
		5 = standing on one bent leg	
		6 = kneeling on one or both legs	
		7 = walking	

The posture code is given after an assessment is carried out using the OWAS worksheet assessment table. Posture codes are used to determine the level of bad work posture and help companies determine priorities for improvements that need to be made. In code A, the worker's working position is considered ergonomically good and does not need to be repaired. Meanwhile, in code B, the worker's working position is still quite good ergonomically but requires less complicated corrective action. In code C, the worker's working position is not ergonomically good and requires relatively difficult corrective action. Meanwhile, in code D, the worker's working position is ergonomically very poor and needs to be repaired as quickly as possible to prevent work injuries.

Posture codes are used to determine the level of poor work posture and help companies determine the priority of improvements that need to be made. In code A, the worker's work position is considered good ergonomically and does not need to be improved. While in code B, the worker's work position is still quite good ergonomically but requires less complicated corrective action. In code C, the worker's work position is not ergonomically good and requires relatively difficult corrective action. While in code D, the worker's work position is very bad ergonomically and needs to be improved as soon as possible to prevent work injuries.

The assessment is carried out by giving a score to each body part in the observed working position. Scores are given based on the categories determined in Table 2, namely 1 for ergonomic body posture, 2 for less ergonomic body posture, and 3 for very less ergonomic body posture. After that, the scores for each body part are added up and the results are compared with the OWAS table to determine work postures that are not ergonomic and need improvement.

Table 2. OWAS worksheet assessment (worksheet)

Back	Arms	Legs																				
		1			2			3			4			5			6			7		
		Load			Load			Load			Load			Load			Load			Load		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

INTERPRETATION OF THE RESULT
1 - No actions required
2 - Corrective actions required in the near future
3 - Corrective actions should be done as soon as possible
4 - Corrective actions for improvement required immediately

1. Preparation phase
    a. Identify research objectives and problems to be solved.
    b. Create a theoretical framework based on related literature.
    c. Determine the research methods to be used and the tools needed.
2. Data collection stage
    a. Observing highway construction workers.
    b. Retrieve workers' work position data using the OWAS method.
    c. Record data in tabular form.
3. Data analysis stages
    a. Calculate the total score for each job observed.
    b. Determine the posture code for each job based on the OWAS table.
    c. Analyze the results and determine the work posture that needs to be improved.
4. Corrective action stage
    a. Designing corrections for non-ergonomic work postures.
    b. Develop an action plan to implement the improvements that have been designed.
5. Evaluation stage
    a. Evaluate the effectiveness of improvements that have been made.
    b. Identify additional improvements needed.
    c. Create research results reports.

In this study, researchers will take samples from 12 highway construction workers who worked on the same project in two different locations on a village road in Aceh Besar district: (1) Jalan Pertama II, Keutapang Aceh Besar and, (2) Jalan Bueng Bak Joek, Kutabaru, Blang Bintang Lama, Aceh Besar.

Observations will be carried out on various construction works such as excavation, leveling and paving roads. The data collected will be recorded in tabular form and will be analyzed using the OWAS method (Table 3).

After the data is analyzed, researchers will determine work postures that need to be improved and design improvements for each posture that is not ergonomic. Designed improvements will be implemented and evaluated to determine their effectiveness in reducing the risk of injury and increasing worker productivity.

3 Results and Discussion

Based on the field survey, there are various activities being carried out. However, this study will only observe the tasks performed by construction workers without involving heavy machinery. The aim is to obtain data on the positions of field construction workers during asphalt paving activities and ensure that they are performed correctly and appropriately. Additionally, the researcher took field photographs to calculate the distribution of construction workers' postures in road construction and categorize the level of actions taken (Fig. 1). Subsequently, the OWAS method was used for the calculations. From the observations, 13 field activities involving construction worker tasks were identified, such as activities numbered 1, 2, 3, 5, 7, 8, 9, 11, and 13. Field tasks involving heavy machinery, such as activities numbered 4, 6, 10, and 12, will not be examined in this study as the focus is solely on the tasks performed by the workers.

Fig. 1. The positions of field construction workers.

Table 3. Recapitulation of observation time

No.	Type of work	Time Observer ran (minutes)	Time Standard (minutes)	Time Cycle (minutes)	Information
1	Workmanship Road Body	60	45	5	Bunched posture lol
2	Alignment Paving with Screws	75	50	7	Twisting posture
3	Interesting Asphalt from Machine	50	35	4	Bunched posture lol
4	Work Side Alignment Narrow	65	40	6	Posture is not comfortable
5	Casting Narrow Side Road	40	30	3	Static posture
6	Alignment Paving Manual	55	45	5	hunched posture

Column description:

No. : sequence number of the observed job.

Job type : description of the type of work performed by the worker.

Observation time : time spent observing work in one observation session.

Standard time : the time considered to be the optimal time to complete the job based on industry norms or ergonomic standards.

Cycle time : the duration of one complete cycle of work performed, including rest periods if any.

Based on the field observations, various activities were examined (Table 4). In the first observed activity, which is roadbed construction, it was identified that the task involving a bent back and bent knees position posed a major risk of injury. This conclusion was based on an 11-second observation cycle categorized as OWAS 4141 (twisted and bent back, both arms below shoulder height, standing with bent knees, exerting a force below 10 kg), which falls under Action Category 4 (AC 4) posture.

Table 4. Postures in action categories 1, 2, 3, and 4, for the 9 basic tasks in the study

No.	Task	Action category (second)				Total time
		1	2	3	4	
1	Roadbed construction	4	0	0	7	11
2	Road base leveling	2	10	0	0	12
3	Spreading primer coat	3	13	0	0	16
4	Screw leveling of asphalt surface	3	0	0	11	14
5	Screed leveling of asphalt surface	6	3	3	0	12
6	Cleaning asphalt from the paving machine	6	6	0	0	12
7	Removing accumulated asphalt from the paving machine	6	0	0	8	14
8	Narrow-side leveling work	6	0	0	10	16
9	Leveling narrow-side road casting	2	3	3	6	14

In the second observed activity, which is roadbed leveling, it was observed that the task involving a forward bending position with straight legs had a potential for mild injuries. The 12-second observation cycle resulted in an OWAS category of 2121 (forward bending, both arms below shoulder height, standing with straight legs, and a load below 10 kg), falling under Action Category 2 (AC 2) posture.

In the third observed activity, which is the spreading of the prime coat, it was observed that the task involving a forward bending position with straight legs had a potential for mild injuries. The 16-second observation cycle resulted in an OWAS category of 2121 (forward bending, both arms below shoulder height, standing with straight legs, and a load below 10 kg), falling under Action Category 2 (AC 2) posture.

In the fourth observed activity, which is roadbed leveling, it was identified that the task involving a bent back and bent knees position posed a major risk of injury. The 14-second observation cycle resulted in an OWAS category of 4141 (twisted and bent back, both arms below shoulder height, standing with bent knees, exerting a force below 10 kg), falling under Action Category 4 (AC 4) posture.

In the fifth observed activity, which is leveling asphalt with a leveling tool, it was observed that the task involving a forward bending position with one leg straight had a potential for mild injuries. The 12-second observation cycle resulted in an OWAS category of 2131 (forward bending, both arms below shoulder height, standing with one straight leg, and a load below 10 kg), falling under Action Category 2 (AC 2) posture.

In the sixth observed activity, which was cleaning asphalt from the paving machine, it was observed that the task involving a forward bending position with straight legs had a potential for mild injuries. The 12-second observation cycle resulted in an OWAS category of 2121 (forward bending, both arms below shoulder height, standing with straight legs, and a load below 10 kg), falling under Action Category 2 (AC 2) posture.

In the seventh observed activity, which is pulling accumulated asphalt from the paving machine, it was identified that the task involving a bent back and bent knees position posed a major risk of injury. The 14-second observation cycle resulted in an OWAS category of 4141 (twisted and bent back, both arms below shoulder height, standing with bent knees, exerting a force below 10 kg), falling under Action Category 4 (AC 4) posture.

In the eighth observed activity, which is narrow-side leveling, it was identified that the task involving a bent back and bent knees position posed a major risk of injury. The 16-second observation cycle resulted in an OWAS category of 4141 (twisted and bent back, both arms below shoulder height, standing with bent knees, exerting a force below 10 kg), falling under Action Category 4 (AC 4) posture.

In the ninth observed activity, which is narrow-side casting, it was identified that the task involving a bent back and kneeling with one or both knees had a major risk of injury. The 14-second observation cycle resulted in an OWAS category of 4161 (twisted and bent back, both arms below shoulder height, kneeling with one or both knees, exerting a force below 10 kg), falling under Action Category 4 (AC 4) posture.

Based on the field observations, data on the distribution of body postures, arm positions, leg positions, and exerted force for construction workers performing the nine types of tasks can be presented in Table 5. OWAS identifies Category 3 (AC 3) tasks as poor and having a high potential risk for muscle injuries. Similarly, Category 4 (AC 4) tasks need immediate improvement as they carry a high potential risk and require prompt action for rectification. Each activity was evaluated using the OWAS method to determine the OWAS category of each task performed by the workers, enabling the assessment of potential injury risks in field tasks.

Table 5. Description of all basic tasks, nine tasks performed by construction workers, and four tasks using heavy machinery

Task	Selected for observation
Roadbed construction	Construction worker task
Road base leveling	Construction worker task
Spreading primer coat	Construction worker task
Road base leveling	Motor grader
Screw leveling of asphalt surface	Construction worker task
Asphalt compaction	Tandem roller
Screed leveling of asphalt surface	Construction worker task
Cleaning asphalt from the paving machine	Construction worker task
Removing accumulated asphalt from the paving machine	Construction worker task
Compaction of asphalt layer base	Tire roller
Narrow-side leveling work	Construction worker task
Narrow-side road base casting	Mixer truck
Leveling narrow-side road casting	Construction worker task

Table 6 shows the data on the distribution of Action Categories (AC) that occur in each observed job.

1. Road body work
   a. Action category 1: 36.4%
   b. Action category 2: 0.0%
   c. Action category 3: 0.0%
   d. Action category 4: 63.6%

   In this work, most of the actions taken by workers (63.6%) fall into Action Category 4 (AC 4), which indicates a high potential risk of work injury.
2. Alignment
   a. Action category 1: 16.7%
   b. Action category 2: 83.3%
   c. Action category 3: 0.0%
   d. Action category 4: 0.0%

   In leveling work, the majority of workers' actions (83.3%) fall into Action Category 2 (AC 2), which indicates a small potential risk of work injury.
3. Spreading prime coat (adhesive coating)
   a. Action category 1: 18.8%
   b. Action category 2: 81.3%

c. Action category 3: 0.0%
d. Action category 4: 0.0%

In the work of spreading the adhesive layer, the majority of workers' actions (81.3%) are included in Action Category 2 (AC 2), which indicates a small potential risk of work injury.

4. Paving leveling with couplers
   a. Action category 1: 21.4%
   b. Action category 2: 0.0%
   c. Action category 3: 0.0%
   d. Action category 4: 78.6%

   In asphalt leveling work with screws, most of the actions taken by workers (78.6%) fall into Action Category 4 (AC 4), which indicates a high potential risk of work injury.
5. Paving leveling with leveling tool
   a. Action category 1: 50.0%
   b. Action category 2: 25.0%
   c. Action category 3: 25.0%
   d. Action category 4: 0.0%

   In asphalt leveling work with a leveler, most of the actions taken by workers (50.0%) are included in Action Category 1 (AC 1), followed by Action Category 2 (AC 2) of 25.0%, and Action Category 3 (AC 3) of 25.0%. No action falls under Action Category 4 (AC 4).
6. Asphalt cleaning from asphalt machine
   a. Action category 1: 50.0%
   b. Action category 2: 50.0%
   c. Action category 3: 0.0%
   d. Action category 4: 0.0%

   In asphalt cleaning work from asphalt machines, workers' actions are divided equally between Action Category 1 (AC 1) and Action Category 2 (AC 2), with each having a percentage of 50.0%.
7. Pulling asphalt stacked in asphalt machine
   a. Action category 1: 42.9%
   b. Action category 2: 0.0%
   c. Action category 3: 0.0%
   d. Action category 4: 57.1%

   In the work of pulling asphalt piled up on an asphalt machine, most of the actions taken by workers (57.1%) fall into Action Category 4 (AC 4), which indicates a high potential risk of work injury.
8. Narrow side alignment job
   a. Action category 1: 37.5%
   b. Action category 2: 0.0%
   c. Action category 3: 0.0%
   d. Action category 4: 62.5%

   In narrow-side leveling work, most of the actions taken by workers (62.5%) fall into Action Category 4 (AC 4), which indicates a high potential risk of work injury.
9. Narrow side road casting
   a. Action category 1: 14.3%
   b. Action category 2: 21.4%
   c. Action category 3: 21.4%
   d. Action category 4: 42.9%

   In the narrow side of the road casting work, the workers' actions are divided between Action Category 1 (AC 1), Action Category 2 (AC 2), Action Category 3 (AC 3), and Action Category 4 (AC 4), with a percentage of each 14.3%, 21.4%, 21.4% and 42.9%.

From these results, it can be observed that certain tasks (such as roadbed construction, asphalt leveling with screws, asphalt leveling with a leveling tool, pulling accumulated asphalt from the paving machine, and narrow-side leveling and casting) demonstrate a high potential risk (AC 3, AC 4) for work-related injuries. On the other hand, other tasks have a lower potential risk (AC 1, AC 2). Measures to enhance occupational safety and health are necessary to mitigate the risk of injuries for construction workers in the field.

The results of this study identify six major tasks in road construction that exhibit poor working postures: roadbed construction, asphalt leveling with screws, pulling accumulated asphalt from the paving machine, narrow-side leveling and casting, asphalt pouring on narrow sides, and manual asphalt leveling with a leveling tool (Fig. 2). Throughout the study, all observed poor postures were associated with bending and twisting of the body, which are considered critical and in need of elimination or reduction. To address these issues, it is recommended to utilize heavy machinery that facilitates the workers, such as mixer trucks for transporting cement and tandem rollers for asphalt leveling. Additionally, workers should be provided with awareness of their postures and step orientation, sufficient rest breaks, and reduced working hours.

Table 6. Percentage distribution of the overall posture action category for construction workers doing all nine jobs.

No	Task	Action category (percent)				Total
		1	2	3	4	
1	Roadbed construction	36.4%	0.0%	0.0%	63.6%	100%
2	Road base leveling	16.7%	83.3%	0.0%	0.0%	100%
3	Spreading primer coat	18.8%	81.3%	0.0%	0.0%	100%
4	Screw leveling of asphalt surface	21.4%	0.0%	0.0%	78.6%	100%
5	Screed leveling of asphalt surface	50.0%	25.0%	25.0%	0.0%	100%
6	Cleaning asphalt from the paving machine	50.0%	50.0%	0.0%	0.0%	100%
7	Removing accumulated asphalt from the paving machine	42.9%	0.0%	0.0%	57.1%	100%
8	Narrow-side leveling work	37.5%	0.0%	0.0%	62.5%	100%
9	Leveling narrow-side road casting	14.3%	21.4%	21.4%	42.9%	100%

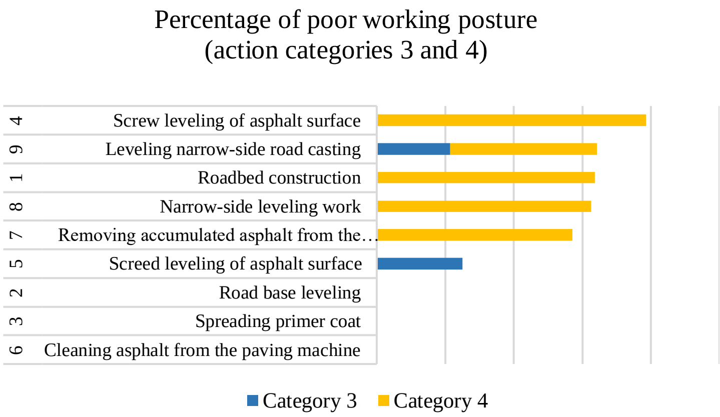

Fig. 2. Poor working postures (action categories 3 and 4) for the 9 basic tasks in this study (%).

This study adopts a distinct approach by dividing construction tasks into basic tasks and observing worker postures separately. This approach offers several advantages, including the identification of basic tasks with a high risk of poor postures, the recognition of postures that have detrimental effects on workers, and the use of the percentage of poor postures as an index of the risk of exposure to poor postures. This index can be used to evaluate the risk of exposure to poor postures in other construction situations by calculating the weighted risk exposure time of the identified basic tasks. With this approach, the assessment of poor postures can be simplified in dynamic construction situations where posture distribution depends on the content of construction tasks.

4 Conclusion

Construction work is dynamic, impacting the distribution of materials and the frequency of construction tasks. Many of these tasks involve poor body postures that pose a risk of injury. Based on the observations and analysis conducted in this study, it was identified that the main tasks with poor working postures in road construction are roadbed construction (AC 4 = 63.6%), asphalt leveling with screws (AC 4 = 78.6%), pulling accumulated asphalt from the paving machine (AC 4 = 57.1%), narrow-side leveling and casting (AC 4 = 62.5%), and asphalt pouring on narrow sides (AC 3 = 21.4%, AC 4 = 42.9%), as well as manual asphalt leveling with a leveling tool (AC 3 = 25%). These tasks demonstrate the poor working postures adopted by construction workers during road construction. Furthermore, it was found that bending and twisting body postures are the main risks for workers, as observed and analyzed, falling into action categories 3 and 4.

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