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COMPARATIVE ERGONOMIC ASSESSMENT OF SLAB FORMWORK SYSTEMS

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The economic efficiency of formwork systems does not depend only on the cost of the product; the achievable performance on the construction site has also a big influence on the selection process. This performance is connected to various factors, such as the number or weight of the individual items, or the required height of the formwork surface. In the course of this research project, four different slab formwork systems performing similar jobs were investigated, enabling a comparison based on an ergonomic assessment. The evaluation of the different systems proved that results and expectations correspond, in this case tasks were reviewed separately for individual systems. Comparing the systems directly, by using the calculated points of the ergonomics evaluation for an average work process, the results display that the least onerous system achieved the highest individual score values. These results led to the assumption that ergonomic scores should not be the sole base for a decision; therefore the performance progress was included and relative ergonomic values for a typical formwork surface were calculated. The result of this evaluation is in line with expectations for the strain of individual systems. The different results between single-task and performance-related evaluations illustrated that, for the assessment of health and safety issues combined with economic factors, not only was the single-task evaluation important, but also an overall view should be taken for a typical scope of work.

Keywords: Slab formwork, Ergonomics, Workload.

1 INTRODUCTION

In the construction industry, economic efficiency is the most commonly-used criteria for decisions on utilizing a specific material or equipment, since for all companies, low costs are usually the only decision tool to acquire a project. Based on national and European programs (EASHW 2004), the focus on Occupational Health and Safety was boosted over the last years. Therefore, in the construction industry the focus was also directed towards the health of workers, and with this change of mind the duties of the construction supply industry also turned to a more prevention-based equipment design.

A major part of the supply for construction companies is provided by formwork companies, who rent their systems to the companies and provide knowledge in the planning process prior to the construction phase. Reinforced-concrete construction is a main part of civil engineering, and health and safety programs within this field are often implemented by formwork companies, since they design the shape of new buildings and the supporting construction within current safety regulations. Therefore, the improvement of formwork systems is important, and combined economic and ergonomic analyses can provide new input for the development process.

2 INVESTIGATION OF THE ERGONOMIC LOAD

The presented idea was an evaluation of the load of different slab formwork systems directly on the construction site by using different analytical methods. The four investigated systems are one “table formwork system”, one “timber-beam floor formwork system” and two “panel floor formwork systems”. Based on this evaluation, the future workload using one of these systems can be estimated within a closer range than at the present time. Also, formwork companies can implement the results into their product development process, especially for the design of the weight and the overall number of pieces, which have to be set.

2.1 Method

The assessment of the slab formwork systems within the research project was executed under scientific supervision by using different investigation methods applied in previous research projects.

The research investigations were started on site to get basic data within four steps: 1) **Investigation of the process**: A modified REFA method (Schlagbauer et al. 2011) was used to divide the investigated task into “activities” and “interruptions”. Then the “activities” were subdivided into different subtasks; subsequently they were classified and evaluated in terms of proportion at the overall performance progress; 2) **Collection of Videos**: The execution of the task was recorded parallel via camera for later analysis of specific tasks with the ergonomic assessment tool; 3) **Investigation of the performance**: The achieved performance progress for a given period or amount of work (e.g., the period between breaks or one room) was recorded during the observation days in order to include the economic evaluation into the results, since the economic efficiency was still the most important variable; and 4) **Monitoring of the heart rate**: For the evaluation of stress and strain, heart-rate monitoring onsite and corresponding laboratory tests were undertaken and the data was integrated into the data pool (Schlagbauer et al. 2012).

After the onsite observation, the final examination of the data was the ergonomic evaluation of the most-frequently occurring activities, using a modified versions of the “Automotive Assembly Worksheet” (AAWS) (Schaub 2004). The AAWS method was especially designed for the automotive industry, but seemed also to fit the ergonomic evaluation in the construction industry. Recently the AAWS method was improved and turned into the European Assembly Worksheet (EAWS) (Schaub et al. 2014). The evolution shows that this ergonomic evaluation method is the right assessment tool for the ergonomic evaluation of construction work tasks.

The results of the ergonomic evaluation were points for all investigated activity tasks. These points were combined with the allocation of tasks to overall points for each slab formwork system. After comparing the points as an absolute number, relative values were also calculated for an improved comparison of the different systems.

2.2 Data Analysis

Performing the data analysis for the four different systems, the results of the task distribution, the according points for each investigated task, and the overall points for each system were collected. The task value was calculated by multiplying the allocation by the mean ergonomic value of the task. The total ergonomic value of each system is the sum of all task values.

For the main tasks, which were divided into different task groups, the ergonomic evaluation could be performed in nearly all cases. For only a few tasks ergonomic values had to be taken from a cross-system evaluation, which was possible due to the similarity of the tasks in all systems.

The ergonomic tasks that were not investigated contain duties outside the scope of formwork (e.g., concreting work), breaks, interruptions of the workflow, and three other parts: (1) additional ergonomic non relevant tasks, which had no connection to the formwork system and were therefore not investigated, (2) unidentified tasks, for which all observations had a small number of tasks that could not be noticed because the worker was out of sight (therefore no ergonomic value could be evaluated), and (3) ergonomic but unclear identifiable tasks, i.e., a combination of many tasks for which the video record showed too small a number for a stable evaluation.

3 RESULTS

3.1 Ergonomic Results

The individual analysis shows the ranking of the different formwork systems according to the ergonomic points (a lower point value means less ergonomic strain for workers): 1) “timber-beam floor formwork system” (25.96 points); 2) “element floor formwork system 2” (27.62 points); 3) “element floor formwork system 1” (30.86 points); and 4) “table formwork system” (31.66 points).

These results are rather surprising, since the “table system” is usually thought of as the system with the lowest strain for construction workers. However these outcomes can be explained by two influence factors: 1) The special arrangement at the investigated construction site: Using the table system, there usually is only one assembly time, but at the investigated site, the construction workers had to assemble and disassemble the tables for every story because of limited storage space. 2) The level of possible performance with the table system: It is usually higher than all other systems.

3.2 Performance Results

The other important data, besides the economic evaluation, were the performance data sets of the different systems, as shown in the following table and compared to values found in the research canon.

Table 1: Comparison of performances of different formwork systems found in this research and historical research in the literature.

Formwort system	Performance value [m2/h]		
	This research	Historical research	Difference
Timber-beam floor formwork system	13.52	13.89	-0.27
Table formwork system	23.85	29.41	-5.56
Element floor formwork system 1	14.89	*	
Element floor formwork system 2	10.67	15.15	-4.48

* Newly-invented formwork system; no literature data available

Combining the investigated performance data and the ergonomic load, another ranking was created. For an easier comparison of the results, a comparative area of 500m² (a typical slab formwork area that can be set up at once) is taken as the base and the ergonomic points for setting up this area were calculated (N.B.: A lower point value means less ergonomic strain for workers).

Table 2: Comparison of the ergonomic points for an area of 500 m².

Rank	Formwork system	Duration of execution	Total ergonomic points
4	Timber-beam floor formwork system	61.67 h	56.5 (= 61.67/28.33)*25.96
2	Table formwork system	35.00 h	39.1 (= 35.00/ 28.33)*31.66
1	Element floor formwork system 1	28.33 h	30.9
3	Element floor formwork system 2	55.00 h	53.6 (=55.00/28.33)*27.62)

According to Table 2, the ranking of the formwork systems became completely reversed, meaning that the “timber-beam floor formwork system” is the most strenuous system.

4 CONCLUSIONS

Based on the evaluation results, the use of the AAWS method for the ergonomic evaluation of construction work tasks is possible. However, since this tool was not originally designed for the construction industry, the AAWS method should be adapted for a better fit when used to investigate typical construction work tasks.

The results show that each system provides tasks that lead to very high ergonomic point levels, and should be reduced by product developments or the redesign of system parts. This implementation of ergonomic knowledge based on the onsite observations into the product development process could lead to an improvement of workplace conditions.

The final results in Table 2 display the expected ranking of the ergonomic load for the different systems, and the comparison between Tables 1 and 2 show the change in the ranking between absolute and relative points. This leads to the conclusion that an overall review is necessary, one that goes beyond a specific look at single tasks when planning or evaluating construction work tasks.

For example, if only relative points are taken into account, the “table system” with a high performance would not have been chosen because of the high ergonomic load. Otherwise, if the performance had been the only factor, the “element floor formwork system” would not have been chosen because of the lower economic revenue which could be gained. These two aspects represent very different points of view: the view of a company leader (who usually wants the most revenue out of his investment) and the view of a health and safety advisor (for whom the impact on the construction worker is in the main topic). Therefore, the product development has to consider both sides, and future research projects should be set up to be open-minded and focused not only on one single issue.

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