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Development and validation of a method for evaluating temporary wooden guardrails built and installed on construction sites

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ABSTRACT

Wooden guardrails are usually built and installed on construction sites to protect workers against falls. In this context, it is extremely difficult to verify whether they are safe and comply with existing regulations. The present study describes the development and validation of an evaluation method and a test protocol for verifying whether these wooden guardrails are safe and meet the requirements of the Québec Safety Code for the construction industry (S-2.1, r.6) in order to ensure that workers have adequate fall protection. This study shows that some wooden guardrails do not comply with S-2.1, r.6. The evaluation method and test protocol are reproducible and easily applicable on construction sites and can easily be adapted to international regulations.

1. Introduction and origin of the request

Work at heights involves significant risks of falls against which workers must be protected (Cattledge et al., 1996; Kisner and Fosbroke, 1994; Ruser, 1995; Surada et al., 1995; Toscano, 1997). International regulations are clear; workers exposed to a risk of falling 1.8 m (6 ft) (OSHA, 1998) or more (S-2.1, r.6, 2001) must be protected. The primary aim of a fall protection strategy is to prevent falls by eliminating risks at source, by planning the maximum operations on the ground, by having the structure provide protection, or by installing collective protection on the work surface. If elimination at source is impossible, the fall distance must be limited by collective protection consisting of catching surfaces; otherwise, workers must be individually protected with personal fall protection equipment (OPPBTP, 1984).

For a floor, guardrails are the most appropriate means of fall protection. They are an excellent collective protection whose primary function is to prevent falls. Consequently, the forces on the guardrail are static forces, in the order of the worker's weight. Guardrails allow mobility; they dispense the worker from wearing a harness and avoid the installation of anchors for workers' lanyards. The installation of anchors with a breaking strength of 16 kN (3600 lb) or more (ANSI Z359.1-1992, R1999; S-2.1, r.6, 2001) is always problematic, particularly for structures with a light frame and for temporary and/or old structures.

On floors, the tasks to be carried out require a great deal of mobility and rapid movements. This excludes fall protection by travel restraint systems. Many tasks involve backward and rapid movement. This increases the risks of falls due to tripping on protrusions or on obstacles such as various tools and materials on the work surface. In addition, by concentrating on the task to be performed or by moving quickly on the work surface, workers arrive rapidly near the open edge without being aware of it, and in the absence of fall protection, they are exposed to serious risks of falls.

Most of the consulted documents (AFNOR NF P 93-340, 1994; ANSI A 12.1, 1973; ANSI A 10.18, 1983; ASTM E 985-87, 1987; NBC, 2005; NF E85-101, 1983; NF P 73-340, 1994; Occupational Health and Safety Act and Regulations for Construction Projects, 1996; S-2.1, r.6, 2001; S-2.1, r.19.01, 2007) provide the resistance and construction requirements for a guardrail. Inspectors from the Commission de la santé et de la sécurité du travail du Québec (CSST, Québec workers' compensation board) rely mainly on sections 3.8.2 and 3.8.3 of the Québec Safety Code for the construction industry (S-2.1, r.6) to determine whether guardrails fulfill the requirements. However, they say that it is difficult during their construction site visits to verify compliance of the guardrails built and installed on construction sites with S-2.1, r.6. The particular features and variability of each construction site also make their task extremely difficult.

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Following a request from the inspectors from the regional office of the CSST of Laval, this study was carried out in order to develop an evaluation method and a test protocol that will enable the construction industry to verify whether the wooden guardrails built and installed on construction sites are safe and comply with the requirements of S-2.1, r.6.

2. Objectives of the study

The objectives of this study were to:

(i) verify whether the design and installation of wooden guardrails, built and installed on construction sites, are safe and meet the requirements of sections 3.8.2 and 3.8.3 of S-2.1, r.6, in order to ensure appropriate fall protection for workers and to define the anchor parameters;
(ii) develop a method and a test protocol applicable to construction sites that allow the industry to verify compliance of guardrails with the regulations;
(iii) generalize the evaluation method to other regulations.

3. State of scientific and technical knowledge and compliance of guardrails with regulatory documents

In the literature review, we identified many isolated studies on guardrails that address a particular problem. These studies have been published in the form of practical memos or fact sheets (CSAO, 1996; OPPBTP, 1994). Scientific and technical knowledge on guardrails are mainly based on standards and regulations published by standardization and regulation organizations. We identified in the literature few or no test methods for verifying compliance of guardrails built and installed on construction sites with regulatory documents. To verify a guardrail's compliance with a regulatory document, the resistance and construction requirements must be verified. The resistance requirements are verified by testing the guardrail for the most critical combinations of loads that produce the maximum loads and deformations in the guardrail components. The construction requirements are verified by checking the geometrical characteristics of the guardrail. If these requirements are met, then the guardrail will conform to that regulatory document.

Table 1
Resistance and construction requirements of S-2.1, r.6

3.8.2. Resistance
(1) A guardrail shall be designed to
  (a) Resist a concentrated horizontal force of 900 N applied to any point of the top plate
  (b) Resist a concentrated vertical force of 450 N applied to any point of the top plate
(2) Where there is a concentration of workers, as well as other areas where a guardrail may be submitted to unusual pressures, the guardrail shall be reinforced accordingly
(3) Where equipment or materials may fall from one work level to another, precautions shall be taken to avoid this, unless there is a guardrail strengthened for this purpose

3.8.4. Metal guardrails
Metal guardrails shall be designed, constructed, installed and maintained in such a way as to offer a resistance and a safety equal or superior to that required for wooden guardrails

3.8.3. Construction
(1) Any guardrail shall be between 1 m and 1.2 m above the surface on which the worker is working
(2) A wooden guardrail shall consist of
  (a) Top plate not less than 40-mm thick by 90-mm wide, supported on posts of the same dimension spaced at intervals of not more than 1.8 m and placed so that the 90-mm width of the post is on the axis of the width of the top plate
  (b) An intermediate rail not less than 75-mm wide at midway and securely fastened to the inner side of the posts
  (c) A toe-board at least 90 mm high and securely fastened to the inner side of the posts
(3) A guardrail of steel wire ropes shall be maintained rigid by means of a turnbuckle and consist of
  (a) A wire rope at least 10 mm in diameter for the top rail and the intermediate rail
  (b) Steel posts spaced at intervals of not more than 3 m
  (c) A toe-board of at least 90 mm high and securely fastened to the inner side of the posts

3.1. Construction and resistance requirements of S-2.1, r.6

Table 1 gives the resistance and construction requirements of S-2.1, r.6.

4. Procedures for verifying compliance of wooden guardrails with S-2.1, r.6

The approach followed includes the following steps:

(i) observation on construction sites and interviews with occupational health and safety (OHS) coordinators;
(ii) development of a method and a test protocol for verifying compliance of the wooden guardrails built and installed on constructions sites with S-2.1, r.6;
(iii) laboratory tests for evaluating the resistance of guardrails according to the test protocol;
(iv) analysis of results and formulation of recommendations.

4.1. Observation on construction sites

First, we observed construction sites in Montréal in order to focus on the wooden guardrails built and installed on these sites. The many parameters to be considered, including the nature and conditions of the materials used, the assembly and its quality, and the anchoring conditions, do not promote the application of classical formulas of strength of materials or finite element methods for verifying the compliance of these wooden guardrails with the regulatory documents. Consequently, the simplest and quickest method for verifying a guardrail's compliance with a regulation or standard is to carry out on-site tests by applying the forces stipulated in these documents' resistance requirements. Due to the production constraints and safety problems that this raised on construction sites, carrying out on-site tests was not the most appropriate procedure. One approach was therefore to reconstruct in the laboratory the guardrails observed on the construction sites, by using the same on-site building techniques. The tests could then be carried out safely in the laboratory.

Second, we conducted detailed observations of guardrails in collaboration with the inspectors of the regional offices of the CSST in Laval and Montréal. Among others, these observations allowed us to:

- discuss with the superintendents, foremen and OHS coordinators, the qualities of a good guardrail and the difficulties encountered during their use on construction sites;
- identify the detailed installation conditions for these guardrails on construction sites, including the technical, geometric and material characteristics of the components of the guardrails built and installed on construction sites;
- identify the different conditions for assembly on false work;
- document in photographs and on videocassettes the main types of guardrails installed on construction sites.