The passive-active concepts as selection criteria for rebar installers' fall arrest systems (PPE)

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Abstract. Personal protective equipment PPE are the last mean for a worker to protect himself. A PPE bad selection leads to refusal or jeopardizing the equipment. The active/passive criterion results from the users' obligation to act (active) or do not act (passive) to make the PPE effective. Rebars are steel round bars used to reinforce the concrete. They are placed and tied in vertical walls manually. 3 fall arrest systems were evaluated: (1) a fixed length lanyard dorsal attachment, (2) a fixed length lanyard sternal attachment and (3) a self-retracking (variable length) lanyard dorsal attachment with a fixed anchor at the top of the wall. System 3 is preferred because it causes the least interference with the task and is the less active one. Their preference is now explained by the active-passive concept.

Keywords. Personal protective equipment (PPE), active, passive, fall arrest system

1. Context

Personal protective equipment PPE are the last mean for a worker to protect himself. To protect, a PPE shall be worn. Therefore a close interaction between the equipment and the user exists. The optimal level of protection is the highest at which the effective use, being 100% of the time by 100% of the users, begins to decrease. The user wants not to be bothered by the PPE. The annex 2 of the European directive 89/686/EEC on PPE stipulates:

"1.1.1. Ergonomics "PPE must be so designed and manufactured that in the foreseeable conditions of use for which it is intended the user can perform the risk-related activity normally whilst enjoying appropriate protection of the highest possible level".

1.2. Innocuousness of PPE

1.2.1. Absence of risks and other 'inherent' nuisance factors

PPE must be so designed and manufactured as to preclude risks and other nuisance factors under foreseeable conditions of use.

1.2.1.3. Maximum permissible user impediment

Any impediment caused by PPE to movements to be made, postures to be adopted and sensory perception must be minimized; nor must PPE cause movements which endanger the user or other persons on the absence of inherent nuisance factors"

How to demonstrate that they are achieved, are they measurable, what

parameters shall be measured: all these questions must be answered to make the requirements more that principles.

A general methodology of selection for PPE including the 89/686/EEC directive principles was presented by Desjardins-David and Arteau; the methodology covers 17 criteria grouped in 4 classes. Are the generic criteria enough? Two accident analyses had showed that a wrong selection had lead two workers to prioritize productivity instead of safety causing their death (Arteau 2012). These workers were using the PPE but they jeopardized their mechanism because the PPE were too cumbersome. The active/passive criterion seems to be the key to understand these behaviours.

The definition of active and passive is revisited. The user reacts to the bother, the interference caused by the PPE. The relationship between the level of activity, the bother and the interference is explained to propose a variable that measures the level of activity. Results from a previous study on fall arrest equipment for rebar installers are reinterpreted using the level of activity.

2. Active/passive concept and related variables

2.1 Definitions

Active equipment needs an action by the worker for its first set-up or when the worker is performing his tasks. Passive equipment requires no action by the user neither for the set-up nor during the tasks (Séguillon and Arteau). As defined, equipment is either totally active or totally passive (CSA-Z259.16-04(R2009)). This concept is rarely used. The reasons are: because most collective protective equipment are passive and most individual protective equipment are active, the collectiveness criterion supersedes the activity criterion. Even a collective passive protective equipment as a guardrail needs to be installed to protect several persons. A level of activity could be defined because a PPE is not totally passive neither totally active. A scale is created from zero totally passive to 1 very active. Also depending on the phase, a system or equipment could be active during the installation while it is passive during the execution of the task. Table 2 illustrates this fact.

When a PPE is inappropriate for the tasks, the user expresses his concerns by saying: the PPE is causing problems, it is not comfortable, I cannot “perform the risk-related activity normally whilst enjoying appropriate protection of the highest possible level”, the PPE is a “nuisance factor”, the PPE is “impeding movements to be made”, I am bothered, annoyed, disturbed by the PPE; the PPE is unsafe. These words express a perception but do not give the reasons and the causes. Then the annoyance in the PPE context could be defined as:

- Impediment of doing correctly the task;
- Impediment or limitation of movements and actions;
- Blockage of the displacement;
- Imposition of an action for the user.

When doing his tasks, the user acts on the PPE either to reduce the annoyance or to readjust the PPE in an appropriate position to regain comfort. So more annoyance will lead to more actions form the user. A correlation annoyance-action could be developed. So annoyance and discomfort are concepts related to the perception while actions or movements done by the user are real and measurable.

But the tasks required by the employer or the contract require a certain amount of movements or actions to be done in a prescribed amount of time. The number of actions per unit of time is limited. If an improper PPE needs many corrective movements, less time is left free for productive work. So a conflict between task and safety is created; as proven by some accident analyses, workers could select the work instead of safety (Arteau 2012).

For optimized PPE selection, a concept seems interesting: active/passive. An active equipment is one requiring actions for the user while a passive one does not required an action from the user to make his equipment effective. The level of user's intervention varies for different PPEs from the same category. This level seems to be measurable.

2.2 Research questions

Is the number of actions done on the equipment to maintain it effective, a measurement of the activity level? Is the activity level related to the interference with the worker's main tasks? What is the workers' preference: active or passive?

3. Methodology

A comparative evaluation of fall arrest systems for rebar installers (Arteau et al 2008) had demonstrated the feasibility of fall arrest systems and of the use of harness. A traditional work positioning belt was compared to several harnesses; harnesses were perceived as equivalent to the belt. Several fall arrest connecting linkages were compared and all were acceptable some more than others. But the study did not explain why some components or systems were preferred; it was not the objective of that previous study. A new analysis of these results under the perspective of active vs passive is presented in order to explain the workers' preferences.

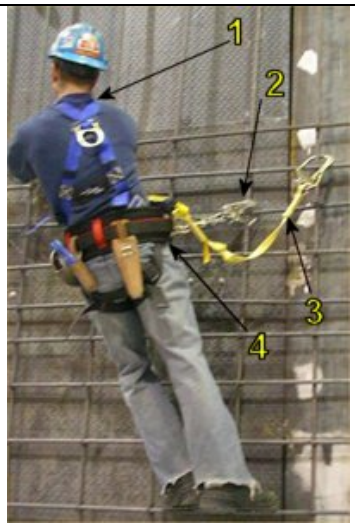
4. Methodology

4.1 Test procedure

Rebars are steel round bars used to reinforce concrete used as structural members in buildings. During a control experiment, 12 workers place the rebars on a large wall and tie them according to the drawings (Figures 1 and 2). Their perceptions were collected by questionnaires and interviews. The independent variables are 3 fall arrest systems: (1) a fixed length lanyard dorsal attachment L5, (2) a fixed length lanyard sternal attachment L6 and (3) a self-retracting (variable length) lanyard dorsal attachment with a fixed anchor at the top of the wall L7 (Figure 1 and Table 1). The dependent variables are: ease of use, discomfort at the shoulder level, discomfort at the hip level, perceived safety and general appreciation. The data and the video already collected were analyzed.

L5 lanyard dorsal attachment
L6 lanyard sternal attachment
L7 self-retractable fall arrester

Figure 1 *Rebar installers on a wall.*



1 –harness
2- positioning chain with snap-hook
3- L6 lanyard sternal attachment
4- positioning belt (harness class P)

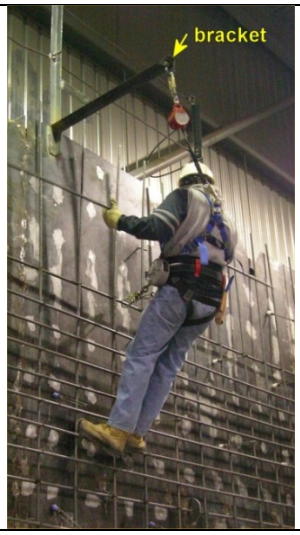
Figure 2 *Fall arrest system and positioning equipment*

The harness with a positioning belt (Figure 2 – components 1 and 4) was the same during the experiment for all workers and with L5, L6 and L7.

4.2 The independent variable: the connecting linkage.

The connecting linkages are described in Table 1.

Table 1 : *Fall arrest connecting linkage and their characteristics*

L5 (LEAD)	**L6 (LEAS)**	**L7 SRL**
Lanyard with energy absorber	Lanyard with energy absorber	Self-retracting lanyard on fixed anchor bracket
1,5m	1,2m	3,3m
Dorsal attachment	Sternal attachment	Dorsal attachment
Class A harness	Class L harness	Class A harness
		

4.3 Discussion

The results of the 2008 study were: for the ease of use: L6 difficult and L5 and L7 equally easy to use; the discomfort at the shoulders: all equally not bothering; discomfort at the hip: L6 is causing some bother; the safety perception: all safe (obvious because with all, they are protected) and the global appreciation, L7 > L5 > L6. In the new analysis, discomfort at the shoulder level and discomfort at the hip level were not considered because they are related to the harness. The ease of use and the general appreciation were reinterpreted.

The workers are placing rebars in front of them in the space between themselves and the wall. They fix the positioning chain on a rebar in of them. Among the 3 systems evaluated during this work, systems L5 and L7 were preferred because the lanyard attached at the dorsal D-ring does not cause obstruction between the wall and the worker. L6 with the sternal attachment is in the front interfering with the positioning chain and the rebars. The system L7 is the overall preferred because no relocation of the lanyard for fall arrest is needed; the anchor at the top of the wall, the self-retractor and the length require one action for protecting the worker continuously. Therefore system L7 which causes the no interference with the task is the less active one. Their preference is now explained by the active-passive concept.

5. Conclusions

5.1 Practical implications

To select PPEs in a hazardous situation, first the compliance to the appropriate regulations and standards is mandatory. But after, how to choose between several certified equipment? The methodology proposed by Desjardins-David and Arteau should be used. Than the active-passive criteria could be evaluated by simply estimating or observing the number of movements done by the workers on the specific PPE while performing their tasks. The PPE requiring the least number of movements is the least active and should be chosen.

5.2 Productivity

PPE who causes discomfort, constraint of movements, or interference with the tasks will requires the user to act on the PPE, to replace it to contravene the constraint or the interference. The actions are real and countable. The total number of actions per time unit is limited for a worker. He is paid for the productive actions he performs. So more actions are required on the PPE, less productive actions are possible leading to a conflict between the tasks and his protection.

5.3 Level of activity and work phases

Table 2 shows that the level of activity is function of the phases of work. The level of activity “During the main task” is the most important but other phases should be considered. The table illustrates that even passive equipment needs some actions before for the set-up and for maintenance. Finally one active component of a system makes the system classified as active.

***Table 2**: Level of activity of different components in function of the work sequence*

	Component of fall arrest system FAS	**Before the task: Donning**	**During the task:**	**After the task: Maintenance**
(1)	Harness	Active	Passive	Active
(2)	Energy absorber	Passive	Passive	Active
(3)	Dorsal lanyard **L5**	Passive	Mostly passive	Active
(4)	Sternal lanyard **L6**	Passive	Mostly active	Active
(5)	Self-retracting lanyard on a fixed anchor **L7**	Active	Passive	Active
(6)	Work positioning belt	Active	Passive	Active
FAS **L5 = (1)+(2)+(3)+(6)**		Active	Mostly passive	Active
FAS **L6 = (1)+(2)+(4)+(6)**		Active	Mostly active	Active
FAS **L7 = (1)+(5)+(6)**		Active	Passive	Active

5.4 Concepts

The number of actions to activate (make the PPE effective) could be a good preselecting indicator. The selection of the least active PPE or the more passive one meaning less interference with the tasks will lead to a greater acceptability, a 100% of users during 100% of the time. This acceptability is in agreement with clauses 1.1.1 and 1.1.2.1 of Annex 2 of the European directive 89/686 on PPE.

The active/passive criterion results from the users' obligation to act (active) or do not act (passive) to make the PPE effective. Active and passive criteria are not dichotomous; the level of activity is the correct representation from 0 passive to 1 active. The number of actions by the user on the PPE is a measure of the level of activity. The number of interventions varies for different PPEs of the same category protecting for the same hazard; so some PPEs are preferred. The least active fall arrest system was the preferred one by rebar installers.

6. References

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