# PREVENTION GUIDE FOR DESIGNERS BASED ON ANALYSIS OF ABOUT 2000 ACCIDENTS

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Abstract: Accident prevention in the design stage of the project is characterized by proactive and effective actions, and analyzing the risks of accidents at the beginning of the life cycle of the project can ensure that safety measures at the stage of implementation, of maintenance and of deconstruction are already in place. This thesis aims to contribute to filling this gap by presenting a proposal for a management model of the prevention of risks of accidents at work at the design phase. This model was obtained by analyzing accidents at work occurring in the construction sector in order to identify links between the causes of accidents and the designs. In order to do this analysis the MAARD-Method of Analysis for Accident Related Design was created and applied. The method results in an analysis in which a conclusive answer can be obtained about the existing link between the causes of the accident and the different types of designs in order to determine which could be involved. The preventive measures to be implemented in design phase were also determined. Based on the analyses of accidents a framework for designers was created. The framework originated a model called MMPtD - Management Model for Prevention through Design. This model consists mainly of a guide that may help designers decide measures to prevent risks during construction. Another conclusion from the study was that an average of 60.8% of the accidents could have been prevented during the stages before construction. Excluding the planning phase from this analysis an average of 35.1% of accidents could have been prevented with measures during the conceptual design. Of these designs architecture and structure designs were singled out as projects of greater impact in the prevention of accidents.

Keywords: accident prevention, construction, designs, risk analysis, safety at work.

## INTRODUCTION

The construction sector stands out with one in six fatalities occurrences in labour accidents. Per year, it is found at least 60,000 deaths at construction sites around the world, leading to an estimate of a deadly accident every ten minutes (ILO, 2010). The EU countries accounts for less than 2% of fatal occupational accidents at work places in the world. In WHO regions the statistics point out Asia and the Pacific region with 64% of the 60.000 fatal accidents at work, followed for Americas (17%), Africa (10%) and Europe (9%) (Dias, 2005).

In numbers, around 1,300 workers per year are victims of fatal accidents in construction sites in the EU. That is equivalent to 13 employees in each 100,000, i.e. more than twice the average of other sectors. According European Commission (2004) and EU-OSHA (2009), the costs of accidents are of particular concern to small and medium-sized enterprises because SMEs account for 82% of all occupational injuries and 90% of all fatal accidents. The European Foundation for the Improvement of

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Living and Working Conditions (1991), through a study conducted in 1991 says that 60% of fatalities are coming from decisions taken before the commencement of activities of the construction sites and could have been avoided with the adoption of appropriate measures at the design stage.

The main motivation for this study was the creation of a safety coordinator in the design stage by the Directive 92/57/EEC - Temporary or mobile construction sites. The directive justified the creation of this activity mentioning that:

"Whereas unsatisfactory architectural and/or organizational options or poor planning of the works at the project preparation stage have played a role in more than half of the occupational accidents occurring on construction sites in the Community;"

However no supporting data was found in a thorough research about the origins and causes for the above quoted statement about over half of accidents being prevented in the preparatory stage of construction works. Therefore a study was performed to verify the value by a doctoral student from the University of Recife, Brasil supervised at the University of Porto, Portugal between 2009 and 2013. (Silva, 2013).

## PREVENTION THROUGH DESIGN

The Prevention through Design – PtD is a relatively recent concept in order that the first research and publications dating back in the early 1990's. This work, has adopted the concept defined by the National Institute for Occupational Safety and Health – NIOSH (2010), in which the PtD is seen as the "Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment."

Accident prevention through design was first suggested in the Accident Prevention Manual from the National Safety Council – NSC in 1955. However, further initiatives may be cited. Research undertaken in the 1990's, that was funded by the Construction Industry Institute-CII in the United States, ended with the production of a computational tool for designers. Currently, several countries like the United States, Australia and European Union countries are engaged in studies on the prevention of accidents through the design, with groups of specific jobs to use as examples.

In the US, many owners of construction companies have had major safety concerns in their projects, starting from contractual decisions when they hire companies who are most committed to safety. The responsibility for safety in the workplace is first placed to the employer, - usually the general contractor - many companies fail from security procedures in the light of the high costs arising from occupational accidents (Gambatese and Hinze, 1999). Thus, many business owners encourage designers to incorporate safety at work on their designs. Some designers, especially those of design and construction companies, already include safety in their designs.

In Australia, the Australian Safety and Compensation Council - ASCC is the largest organ responsible for OSH Regulations Act, which replaced the NOSHC in October 2005. It is a tripartite body which emanates consultative guidelines for voluntary compliance integrated by the laws of each jurisdiction, i.e. for each State of the Commonwealth, - called the Australian Central Government.

In 2002, States, territories and the Commonwealth Ministers, leaders of the Australian Chamber of Commerce and Industry and the Australian Council of Trade Unions

signed a 10 year national strategy for safety at work. The national strategy establishes two goals to achieve by June 30, 2012: reduce fatalities by at least 20% and reduce the incidence of injuries at least 40% (Creaser, 2008). One of the studies databases to establish the elimination of risks in the design phase as the fourth priority refers to the investigation of accidents occurring between July 2000 and June 2002 in Australia, they were verified aspects related design (Driscoll et al., 2008).

In the EU, the duty to implement safety was the responsibility of the contractor as the performer of the work, but the legislation has changed this situation and implementation of prevention measures is not dependent on the contractor's only but also on the owner and on designers. This integration is justified by the fact that decisions of preventive measures taken at design level are related with safety coordination activity, that in itself is also a design (Soeiro, 2009).

In the United Kingdom, the transposition of European Directive 92/57/EEC of June 24, 1992, through Construction Design Management Regulations 2007 – CDM 2007 required that designers consider aspects of occupational safety in all phases of the construction, and it will be subject to litigation, fines and imprisonment. The CDM emphasizes the identification and assessment of risks, and determines the required steps for the integration of safety at work in the design, involving the designer directly. The Health and Safety Executive - HSE created the Safety in Design – SID, an entity that seeks to share ideas, suggest choices, educate and inform concerned professionals about their performance and duties (CDM, 2010).

## DESIGN AND CONSTRUCTION SAFETY

The designer has been identified as a construction worker holding great impact on safety at work. Historically, although designers do not take into account the safety in designs and often are not aware of the impacts of their decisions design in the safety of construction. The development of design is an activity of increasing complexity. It surpasses the technical concepts as commonly used and requires an overview of the various businesses involved and other aspects of activity.

Some authors distinguish design management to design coordination, featuring management as an activity linked to the development of generic procedures and coordination activity specifically linked to implementation in a given undertaking. They define the design coordinator as the principal agent in the management of the design process and have their principal tasks as performing actions of integration between designers; coordinating and controlling designs and exchanges of information in order to ensure that the design process meets deadlines and objectives.

In the European Union, there is also the coordinator for safety and health in design phase, defined as the natural or legal person, who performs during the preparation of the design, the tasks of coordination in the field of occupational safety and health, provided for in applicable legislation, and may also participate in the preparation of the contract negotiation process and other preparatory acts of construction works, concerning safety and health at work (Portugal, 2010).

In the field of occupational safety, design solutions already exist for most problems, but the challenge is to make changes to ensure that risks and hazards can be eliminated and/or minimized at source (Creaser, 2008). Don't just point out what to do; you need to show how to do, i.e. define methods for the viability of the insertion of the safety considerations in the planning stage. Many designers fail to show how

their designs can ensure the safety of future workers. In addition there are too few tools and materials available for queries in order to assist them in recognition of risks and the adequacy of their designs.

## STUDY ACCOMPLISHED

To understand the functioning of safety at the design stage, some questions are required, such as: What are the tasks in each type of design? How would be the workflow design? How would be the management of the flow of work and information? Other issues were also raised: Does the few existing manuals and computational tools in support of the originator apply to any region? Should there be an adaptation to the conditions of cultural, social and economic individuals to each location? Is it from the analysis of the causes of accidents at work, according to official data, that we can detect relationships with the design?

With the intention of answering some of these issues and in order to assist designers and construction owners directly, a study was done with the aims of producing a model for the integration of safety at work in the design process using a practical guide for designers containing guidelines for safety at work. This analysis was based on the development of a risk assessment method for the design phase.

The model aimed at contributing in the prevention of risks of accidents in construction during the lifetime of the project (planning, implementation, maintenance and deconstruction), taking into consideration design decisions, accident risks and control measures.

The research study consisted of the following steps:

a) Identification of key stakeholders (owner, co-ordinator, designers, etc.) and their respective duties in construction safety, specifically in the sub-sector of buildings;

b) Analysis of the design process;

c) Search for statistics on construction accidents in order to understand the underlying causes and respective risks that originated the accident;

d) Analyze case studies in order to establish the possible links between the causes of the accident and the design decisions;

e) Method to assess risks at the design stage that could eliminated or alleviated;

f) Guide for designer containing guidelines for preventing accidents at the design phase.

## RESULTS AND CONCLUSIONS

Literature in general presents the benefits of preventing accidents through design, show project viability, and makes projections for the future. Furthermore, in some countries the legal responsibility of safety in the workplace is also shared with the designer. However, practical material available to the designer is still lacking. Considerations of safety at work in practice are insufficient and there are still many difficulties and lack of awareness. In order to make prevention through design, it is necessary transformations in the attitude of project stakeholders, moved by awareness instead of law force. The safety at work is a responsibility of all society, and designers

are holders of expertise. They have at their hands a great potential to promote safety thorough their designs.

The number and sources of accidents analysed was diversified in terms of sources. The accidents were obtained directly from public sources and from one Brazilian construction company. This data from public sources was obtained from reports of accidents available for the public. The data obtained from the construction company was obtained from consultation of the company records.

The numbers of accidents analysed in this study were 675 from the construction company in Brasil, 940 from CCOHS in Canada, 116 from FACE, NIOSH and PtD in USA, 203 from ACT in Portugal, 100 from HSE in United Kingdom, 41 from WSH Council in Singapore and 32 from SFIT in Brasil. The period of time when accidents were analyzed was from 1995 until 2012.

This data obtained from the analysis of about two thousand fatal or serious accidents originated the following conclusions about the percentage of accidents avoidable in design phase:

a) Minimum found in one of the countries - 23.6

b) Maximum found in one of the countries - 45.0

c) Average for the total of accidents in the seven countries- 35.1

These values were obtained using the MAARD model described ahead. The main considerations of the method were: a) accidents occurred because there were risks taken; b) some of the risks could have been avoided taking preventive measures at the design stage; c) percentages were obtained counting the number of accidents where the preventive measures could have been taken and, as consequence, the accident could have been avoided. Countries have different processes for accounting fatal accidents in terms of period of monitoring the accident, of the place where death was declared or recording the accidents in public reports. Besides these differences there were other possible reasons to have these differences like working methods, design procedures and safety control at design phase. These disparities may explain the variation of values.

Taking into account the different type of designs (infrastructures, superstructures, mechanical, electrical, HVAC, architecture and water systems) two models were created to help the prevention of accidents at the design phase. These were called MAARD (Method of Analysis for Accident Related Design) and MMPtD (Management Model for Prevention through Design). (Silva, 2013).

For designer guidance the model, designated as MAARD (Method of Analysis for Accident Related Design), is composed by a matrix that relates the frequency and the gravity of accident with the possible preventive measures to be considered at the phase of design. These preventive measures were chosen based on the risks that created the accident analysed. The measures were identified as possible to be decided during the design phase. This tool allowed the conclusion of how many accidents could have been prevented at the design phase, planning phase and construction phase.

The second tool created based on this research study was MMPtD (Management Model for Prevention through Design). It is composed of four sets of checklists that are supposed to be used by designers according to the respective type of design: architecture, structures, infrastructures and mechanical/electrical installations. These four guides are practical tools that can be used by any designer without an enlarged

knowledge about prevention of accidents. This guide is expected that, if widely used by designers, there will be a serious reduction of accidents in construction since more preventive measures were taken at the design phase. Both tools are available for public consultation and can be obtained from the authors of the article.

As a further reflection about future research and about arising issues the following questions can be made:

a) Is it worth having a safety coordinator at design phase? The percentage of accidents that could have been prevented in the design phase is below the value presented in the directive. Taking into account that the fact that one accident prevented is reason enough to have a safety coordinator in the design phase the question is if the reason invoked in the directive is still valid. Further research could be done to benchmark the current results. The number of accidents analysed is large in total but reduced in each of the sources from the different countries.

b) Is it better than the safety coordinator at design phase to use a guide for designers to prevent accidents? The effectiveness of safety coordinator at the design stage can be replaced by a wider and globalised use of MAARD and MMPtD tools if accepted by the designers´ community. Here the professional associations and regulatory agencies can have a significant impact in accident prevention.

c) How can this study work with others already done and with future research? In fact an organized and systematic effort should be made to research and to analyse accidents that occurred. It is important to learn from these accidents so the accidents that could have been prevented do not happen anymore. For this initiative it would be important to have public data and investment in research and analysis. Technological platforms can be used to manage the knowledge about the preventive measures in construction.

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