Construction Materials

INTERSECTII
INTERSECTIONS
http://www.ce.tuiasi.ro/intersections

ISSN 1582-3024

Technical, environmental and security criteria of new building materials parameters evaluation

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Summary

The success of new building materials in the market consists in the fulfillment of basic technical, environmental, security and economical demands. It is possible to minimize by means of the preventive FMEA method (Failure Mode and Effects Analysis) already during the development of new materials the risk of qualitative, environmental and security faults, risks and hazards.

The paper discusses the preventive FMEA method applied in the design and development of progressive building materials with utilization of secondary raw materials.

This method can in a basic way assist in the examination of physico-mechanical properties of these materials, in the formation of technical and security certificates and in this way it can eliminate the problems with the material application into structures, caused by users distrust to the secondary raw materials from the point of view of their technical, ecological and precautionary safety.

KEYWORDS: FMEA - Failure Mode and Effects Analysis.

1. INTRODUCTION

The FMEA method is ranked among the basic preventive methods of quality management and it is an important part of the design examination. It is based on the team analysis of possible faults of the examined design, concerning its evaluation, its risks and the realization of measures which lead to the improvement of the design quality.

The experience shows that it is possible by means of this method to detect 70% until 90% of possible disagreements [1].

The use of the FMEA method presents a systematic approach to the prevention of bad quality and it leads to the decrease of losses caused by the poor quality of products, to shortening of the solution period of the development work, to the decrease of changes in the realization phase and to purposeful utilization of sources.

The results of the FMEA method application form a very valuable information data base about the product which can be utilized also for similar products and these results are a significant base for the elaboration or specification of quality plans and an important part of the control system in the area of design formation [2].

The method itself is realized in five steps:

***1st step** – Determination of system elements and of system structure*

The system is composed of system elements (SE), which serve for the description and classification of the hardware conception and are arranged in the system structure. The system structure arranges the individual system elements from up to down on different hierarchical levels. Apart from it, it is necessary to describe the present interconnection of individual system elements as the interface to other system elements.

***2nd step** – Representation of functions and of the functional structure*

The system elements have different functions or tasks in the system. The joint effect of more system elements functions can be demonstrated as the functional structure (the tree of functions/network of functions). For the determination of functional structures we have to monitor the input functions and the internal functions.

***3rd step** – Execution of faults analysis*

We must carry out the faults analysis for each observed element described in the system. The possible faults (F) of this system element are derived from the known function defined in the 2nd step and they describe the faulty functions.

The possible effect of each fault has to be determined and it will be evaluated (quantified) by means of the ten points scale from the point of view of its importance (B).

The possible reasons of faults will be classified owing to the imperfect function of the subordinated system elements by means of the interface to the system element.

The probability of fault occurrence (A) will be estimated for each reason by means of the ten points scale.

The analysis is determined by the specification of existing preventive measures (precautions to prevent the fault formation) and by the introduction of control measures.

The probability of fault sources (mechanism) detection (E) is evaluated in the case of this measures application and it is quantified by the help of the ten points scale.

***4th step** – The evaluation of the risk size*

The risk size (RPZ) is the product of the point evaluation: B – the importance of the fault effect, A- the probability of fault reason occurrence and E – the probability of the fault reason detection.

***5th step** – The introduction of optimization*

It begins with the highest values of RPZ by definition of precaution/preventive measures. These measures have deadlines and they must be taken by appointed persons in charge. The optimization is necessary for high values of the risk factor (RPZ) or high values of B, A and E. The optimization is realized following this order of importance:

- Change of conception – in order to eliminate the reason of fault or in order to reduce the fault significance.
- The increase of conception reliability – for minimization of the fault reason occurrence probability.
- The effective detection of the fault reason (if possible without additionally tests).

The additionally measures for the risk minimization should be described and the responsibility for the realization of these measures must be clearly determined. It is necessary to realize all five steps of the system FMEA for the respective areas in the case of a deciding change of conception.

2. RISK FACTORS ANALYSIS BY MEANS OF FMEA

2.1. Preparation of FMEA – T

The subject of analysis should be determined and the members of the team selected, with respect to the effectiveness, before the beginning of the FMEA methodic application.

The selection of the team members should be made with regard to their activities in the FMEA teams following the criteria:

- FMEA- K (construction FMEA),
- FMEA- T (technological FMEA).

Further the data concerning the process description (the technological procedure), the flow chart with marked checking operations/control of the process (SPC) and information about all former (also only possible) problems with the product/task/process and its solution should be collected. This information should be divided into three categories from the point of view of:

- significance of the fault (the consequences for the client),
- reason of the fault,
- checking or controlling measures (SPC).

2.2. Technical and qualitative demands

The technical and qualitative demands should contain especially the wishes of the client, juristic and other demands and the demands of other interested parties.

2.3. Environmental and ecological demands

The prevention of negative environmental aspects which can occur in the FMEA-T or FMEA-K and in the phase of product utilization or its post-action disposal is in particular the demand of the environmental area. This concern especially the areas connected with the:

- Atmosphere protection,
- Handling with hazardous chemical substances and wastes,
- Water resources management and water protection,
- Wholesome environment (e.g. noise and dust protection),
- Consumption of natural resources (utilization of waste materials – saving of natural sources, utilization of recycled materials),
- Energy saving (heat, electric power).

2.4. Safety requirements

The requirements which follow from the legislation and from demands of labour and health protection - it concerns especially the:

- Identification of hazards, risks and so called accidents.
- Fire safety.
- Hygiene.
- Health protection.
- Users safety.

3. REALIZATION OF FMEA IN THE DESIGN AND DEVELOPMENT OF CONCRETE

3.1. The team composition

Research teams of the research project No.: MSM 0021630511, called “Progressive Building Materials with Utilization of Secondary Raw Materials and their Effect on

ISSN 1582-3024

the Service Life of Structures" are participating on the proposal and development with the FMEA application, by partial subject matters:

- Research and Development of New Types of Concrete, coordinator is Doc. Dipl. Ing. Rudolf Hela, CSc.
- Securing of Concrete Durability, coordinator
- Doc. Dipl. Ing. Jiří Brožovský, CSc.
- Research of New Surface Treatments, coordinator
- Prof. Dipl. Ing. Rostislav Drochytka, CSc.
- Testing of Materials and Environmental Management, coordinator
- Prof. Dipl. Ing. Jiří Adámek, CSc.

3.2. The selection of concrete

One of most widespread building materials in the time being is the concrete, which is in the modern form produced already more than 100 years. The concrete technology has made significant steps ahead in the last decades.

The raw materials used for the concrete manufacture used today we could mark as "hazardous waste" only some years ago. We would be obliged to dispose this waste under increased safety conditions and with financial costs.

These "new" raw material sources can with their physico-chemical properties lower the dement dose for 1 m3 of concrete and after mixing it into the concrete and its hardening these components can take part on the increase of some physico-mechanical concrete parameters and in some case even on the increase of the concrete durability.

Such raw materials are for instance the power plant fly ashes, slag, waste ferrous dust etc. These materials must fulfill the given chemical and physico-mechanical and physico-chemical parameters.

Considering the fact that it concerns mostly the so called "secondary raw materials", i.e. raw materials which are formed as a by-product during the production of another product (material) this by- products don´t have in most cases constant properties. In this way the use of these materials for the concrete production can mean an increased risk.

The analysis and the evaluation of the usability and the risk elimination was tested on three selected types of concrete (common concrete, self compacting concrete and reactive powder concrete). These three types of concrete were produced with the addition of a certain fly ash dose from the power plant Dětmarovice.

3.3. Decomposition and the risk analysis of input raw materials and of the resulting Product

Technical and qualitative demands

This concerns especially:

- The evaluation of input raw material considering the intended use
  - Physico-mechanical and physico-chemical properties
- The properties of fresh concrete
  - Consistency, volume mass, air content etc.
- The properties of hardened concrete
  - Volume mass, strength characteristics, concrete resistance against outer stress, appearance etc.
- The durability of concrete

Environmental and economic demands

These concerns especially the areas connected with the:

- Protection of the atmosphere
- Water resources management and water protection
- Handling with wastes
- Handling with hazardous chemical substances (NCHL)
- Wholesome living conditions (for instance noise and dust protection)
- Utilization of natural sources (utilization of secondary raw materials – savings of natural resources, utilization of recycled materials).
- Savings of energy (heat, electric energy)

Safety requirements

The safety requirements are connected with the utilization of secondary raw materials types which are as safe as possible of with respect to:

- Physico- mechanical and physico- chemical properties
- Storing and transport security
- Possible industrial accidents and professional disease
- Safety of the production technology
- Safety of application into the building structures
- Prevention of undesirable events, accidents and hazards
- Notification and announcement duty according to the legislation of the Czech Republic

ISSN 1582-3024

4. CONCLUSIONS

It holds generally, the sooner in the service life period we succeed to disclose the risk of the improper product occurrence, the lower are the financial losses.

Some practical experience shows, that the costs for the elimination of disagreement in the phase of design can be hundred times lower than the costs for the elimination of disagreement determined for the expedition and thousand times lower, than the costs for the elimination of the disagreement which comes to the client.

It is still a very often event that "it is not enough money or time" to elaborate sufficiently the design and afterwards it must be enough money and time for much more expensive elimination of problems which come into being in the phase of realization [1].

It was in the area of technical requirements determined by the FMEA that in the case of power plant fly ashes application in the production of SCC the pozzuolana reaction of the fly ash comes to light till after 180-days of the concrete age.

Since this time the increase of concrete characteristics took place in comparison with the self compacting concrete, manufactured without the utilization of the power plant fly ash. This showed itself significantly also on the resistance of SCC against individual, selected chemically aggressive media, to which the concrete was exposed.

As the most serious risks and hazards in the field of the environment and safety were identified those potential faults, which are connected with the utilization of fly ashes as the input raw material in the manufacture of SCC.

These risks and hazards are connected specially with the physico-mechanical properties of the fly ash, for instance with the inhomogenous chemical composition, with the specific surface, with the index of efficiency, with specific activity 226Ra etc.

Acknowledgments

The paper was elaborated with the support of the research project No.: MSM 0021630511: "Progressive Building Materials with the Utilization of Secondary Raw Materials and their Effect on the Durability of Structures".

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ISSN 1582-3024