JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT
2010
16(3): 320–331

MAKING SOLUTIONS FOR CHOOSING INDUSTRIAL CONCRETE FLOORS AND EXPEDIENCE OF RELIABILITY EVALUATION

Violeta Medelienė[1] **, Vigantas Antanas Žiogas**[2]
Department of Civil Engineering Technologies, Kaunas University of Technology,
Studentų g. 48, LT-51367 Kaunas, Lithuania
E-mail: [1]*medeliene@gmail.com;* [2]*vigantas.ziogas@ktu.lt*

Received 18 Dec. 2009; accepted 10 Jun. 2010

Abstract. The rapid growth of economy and the recent development of industry in Lithuania have considerably increased, and therefore the need for industrial concrete floors also has a tendency to growing. The floor is used in almost all industrial companies because of differently modified concrete and a number of coating materials. It is more difficult to make an effective solution for choosing the required coating due to the supply of many different coating materials, an improvement in technological solutions, stiffening economic and ergonomic requirements. The article focuses on the complex problems of working towards a solution for selecting coating, presents the evaluation of conditions for floor exploitation and analyses mistakes and economic outcomes. The paper describes the expedience and problems of evaluating solutions for choosing floor covering in terms of reliability, makes the complex model of factors that influence reliability and presents a practical example of calculating statistical reliability.

Keywords: aspects of evaluating solutions for choosing coating, mistakes about decision making, levels of reliability evaluation, complex model of factors influencing reliability, statistical reliability.

1. Introduction

In modern industrial construction, concrete is considered to be the main flooring material. Concrete as a building material has been used and continuously improved since ancient times as it has very high compression-resistant properties, remains durable, resistant to mechanical impact, abrasion and friction as well as can be characterized by low water absorption.

Approximately more than 50% of the total installed floor area in the countries of the European Union is occupied with monolithic concrete floors. Each year, nearly 24 million m^2 of concrete floors is covered with polymer coating. In Germany, the major flooring companies have already installed on average 400 000 m^2 of industrial concrete floors (Seidler 2007).

The number of new or reconstructed industrial companies in Western Europe is growing, and therefore the need for industrial concrete floors is increasing (Perspektiven der europäischen Baukonjunktur 2010). Many economists predict that short-term industry growth in Europe and other developed countries worldwide will have a slightly slower growth in the nearest future while the development of economy is influenced by changes in the markets of growing industry, including China, India, Korea etc. (Complex study of Lithuanian economy growth and competitive ability sources (factors) 2006).

Although Lithuania has always been considered as a traditional agricultural country, however, for several hundreds of years, human industrial activities stimulating changes in our society have been undertaken. The construction of new industrial objects has considerably increased during the periods of independence and integration into the structures of the European Union. The growing possibilities of the Lithuanian market stimulated the development of new or upgraded traditional industry branches. Competitive participation required constructing new factories, warehouses and other utility buildings in accordance to modern standards. The data provided by the Department of Statistics to the Government of the Republic of Lithuania (Department of Statistics to the Government of the Republic of Lithuania 2009) have shown that during the last five years, a very intensive growth of industrial objects have taken place. The analysis of statistical data has revealed that the largest volume of construction work was carried out for industrial buildings and warehouses designed with industrial concrete floors. Demand for this type of floors has increased almost twice in the last five years – from 336,2 thousand m^2 in 2005 to 600,8 thousand m^2 in 2009. Prospects for demand for industrial concrete floors in the nearest decade are perfectly revealed in the new long-term economic development strategy of Lithuania until 2020 concentrating on two main targets: 1) a rapid growth of national economy; 2) the growth of economic international competition (Update of long-term economic development strategy of Lithuania until 2015, 2007). Extending the underlying industrial and agricultural branches of industry, striving to successfully integrate into the world's market and an increase in companies' competitiveness is

ISSN 1392–3730 print / ISSN 1822–3605 online
doi: 10.3846/jcem.2010.37

necessary to modernize old or to build new companies meeting European and worldwide used standards. The growth of industrial objects will increase demand for concrete floors in Lithuania.

The design, installation and use of industrial floors require a proper solution to many complicated problems related to a multi-aspect analysis of necessary concrete properties and a proper selection of concrete composition which ensures concrete suitability for the imposed requirements. More and more complicated problems of concrete floor installing stages are analyzed. In order to ensure environmental requirements, the possibilities of crack appearance are reduced to minimum while using such kind of floors. Surface dustiness is reduced to meet requirements for human health, etc. No matter how effectively you can solve the problems of concrete mix proportioning, floor construction and technological solutions, during operation, they cannot ensure maintaining all properties due to the nature of concrete as a material: concrete dust as a result of a lack of cement-bonded, the occurrence of cracks and the effects of mechanical loading can create conditions for concrete corrosion, and therefore concrete porosity can increase as a result of water and chemical penetration into concrete floor construction, aesthetic image degradation of floor structure etc. A concrete layer is usually enlarged in order to ensure concrete properties during exploitation (Garber 2006; Wiegrink 2007; Lohmeyer *et al.* 2008). The thicker is the layer, the less economical is a solution. The scientific sources (Lohmeyer 2006; Krell 2007; Wagner *et al.* 2007) state that almost all most important concrete properties are necessary only for the top layer and the problems are solved easily by applying coating.

2. The problems of making solutions for choosing industrial concrete floors and the main aspects of evaluation

The surface of industrial concrete floors as well as concrete floors must meet all standard requirements presented in the following documents: technical requirements for the floor under different exploitation conditions, design standard, documents on effect and load setting under different exploitation conditions, standards in using materials, requirements for the used materials affecting the environment, requirements for industrial concrete floor installation.

Requirements for different branches of industry differ, thus various types of concrete layer installation can be applied. The sources of scientific literature (Lohmeyer 2006, 2008; Krell 2007; Wagner *et al.* 2007; Moreira *et al.* 2006; Schuhmann 2005) introducing the main top layer formation means: 1) concrete coating is formed using special treatment technologies (performing usual luting and grinding of the concrete surface, polishing the concrete surface with special polishers and impregnation with special materials, smoothing special invigorating additives into the concrete surface during consolidation); 2) covering the concrete surface with special coatings (seamless castings and unitary materials). Different materials and coating compositions are applied for each solution.

The analysis of scientific sources (Lohmeyer *et al.* 2008; Schuhmann 2005) concerning industrial concrete floor coating technology and regarding the type of coating materials distinguishes four main technological stages: 1) preparation (mechanical grinding, mechanical or manual cleaning, roughening); 2) surface priming (once or twice, depending on concrete foundation condition); 3) coating installation (different coating types and used materials); 4) formation of surface coating (varnishing, coating with a protective layer, forming undulation with a roller, surface top-dressing with various fraction stones, quartz sand, joint slush).

Taking into consideration a large number of standard documents, the number of materials and their systems used for coating and the number of technological solutions making a decision on coating is quite a complicated and complex task to be solved. There are many difficult problems related to: 1) standard document analysis (updating a standard base for industrial concrete floor designing and installation in Lithuania); 2) a set of requirements for the floor and coating of different industry branches; 3) selection of proper materials and systems; 4) an assumption of adequate technological solutions; 5) the evaluation of solutions made to floor coating suitability under exploitation conditions.

These problems have shown the relevance of works published by foreign and Lithuanian researchers widely performing in the area of coating material properties. The mechanical properties of the epoxy coating system are analyzed in researches conducted by White *et al.* (2009), the influence of mechanical load over polymer coatings is assessed by Zeleniakiene *et al.* (2005), the influence of mechanical effects over acrylic coating condition is examined in Kotnarowska's works (2008), the resistance of various polymer coatings to chemical loads was presented by Moreira *et al.* (2006), Figovsky *et al.* (2007), water vapour uptake in water epoxy coatings was discussed in researches by Rufo *et al.* (2007), etc. The problems of coating system design under different affects were investigated by Almusallam *et al.* (2002). The questions of choosing decisions on designing acrylic, epoxy and silicone coating systems considering attributes necessary for concrete protection were investigated by Aguiar *et al.* (2007, 2008), the suitability of concrete floors for various environments was analyzed by Lang (2003), the aspects of concrete coating effectiveness and their influence on concrete longevity were analyzed by Medeiros *et al.* (2009), the issues of designing polymer protective concrete coating and evaluation of reliability aspects were examined by Kamaitis (2007a, b). The influence of a damp concrete surface and concrete bedding adhesion at the stage of industrial concrete floor installation was analyzed by Žiogas *et al.* (2008), Dallons (2008), Jayson, Helsel (2007), Frigione *et al.* (2006), ultrasonic evaluation researches of polymer coating adhesion with concrete bedding were presented by Czarnecki *et al.* (2006), the influence of concrete surface roughness on the adhesion of various materials was analyzed by Czarnecki *et al.* (2006), defect appearance due to the improperly prepared surface was widely investigated by Fitzsimons and Parry (2009), the reasons of

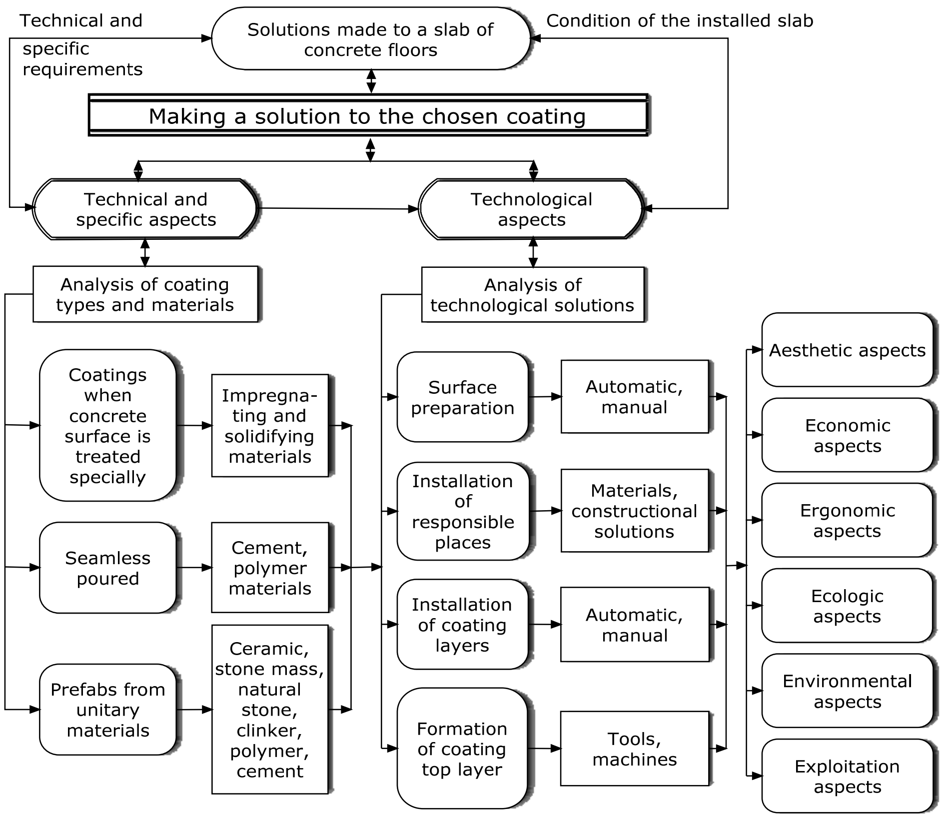

Fig. 1. The aspects of evaluating solutions to industrial concrete floor coating

bubble appearance in epoxy coating were explained in scientific works by Wolff (2009).

The results of the deterioration of coating properties during exploitation at the application stage were presented by Kuisma *et al.* (2009), the methodology of coating slippery applying a calorimeter and scanning with an electronic microscope was presented by Cham, Redfern (2001) suggested research on the influence of different materials on comfort and fatigue as well as evaluated the influence of and correspondence between coating and people's behaviour and carriage.

The topic analyzed in scientific literature shows that decision making about industrial concrete floors is a complicated and very responsible process that requires detailed complex multivariate solution analysis working out solutions taking into consideration not only technical, special requirements, exploitation, technological aspects but also equally important economic, ergonomic, environment safety, ecologic, aesthetic etc. requirements (Fig. 1).

3. Analysis of conditions for the exploitation of industrial concrete floor coating in Lithuania

In order to ascertain the situation how solutions to concrete floor coating were analyzed and performed considering the above introduced aspects and conditions for coating, the analysis of coating was performed in different industrial companies. Evaluating conditions for the exploitation of concrete floor coating in Lithuanian industrial companies, food and chemical industry companies were chosen because of high technical exploitation and other specific requirements foreseen for their concrete coatings exploited not less than for 5 years. Research has revealed conditions for coatings, evaluated solutions for designing floor concrete foundation, identified defects and explained the reasons of deficiency some of which are presented in Figs. 2, 3, 4.

The analysis of floor coating exploitation performed in the companies of Lithuanian industry has showed that when a decision on coating is made, a number of mistakes are done at design stage where the effects of the environments of industrial exploitation are insufficiently analyzed failing to evaluate all exploitation factors. A lot of mistakes are made proposing technological solutions to coating installation, especially in responsible places. However, the encountered problems are found not only in Lithuania. According to the aspects of scientific research in the field of concrete floor coating analyzed in the previous part, it can be noticed that foreign scientists fully analyze the defects and problems of their appearance, offer means to avoid them, introduce a methodology for the early detection of shortcomings etc. The influence of some mistakes suggesting a solution to the state of coating exploitation is presented in Fig. 5.

The result of all these faults is coatings that do not meet requirements for exploitation, and therefore the companies sustain heavy financial losses that involve floor structure, coating repair and even the whole reconstruction. Economic loss that appears when companies have to close departments for repair or reconstruction should be also evaluated. Ecological outcomes are also very important because leaky coatings do not protect

Fig. 2. The view of coating EPIREX 306 affected by the formic acid of strong concentration and caustic soda in the organic department

Fig. 3. PERAN system coating coloured due to constantly running water from the system, JSC *Rokiškio sūriai*

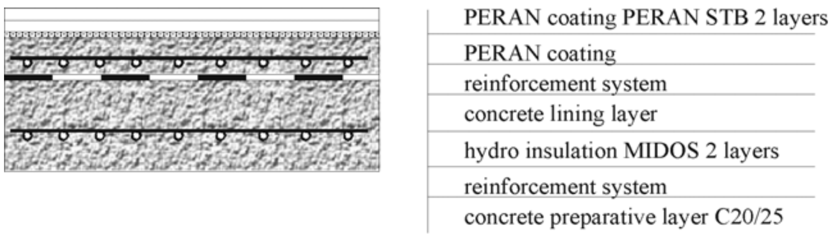

Fig. 4. Floor construction scheme in the production preparation department, JSC *Rokiškio sūriai*

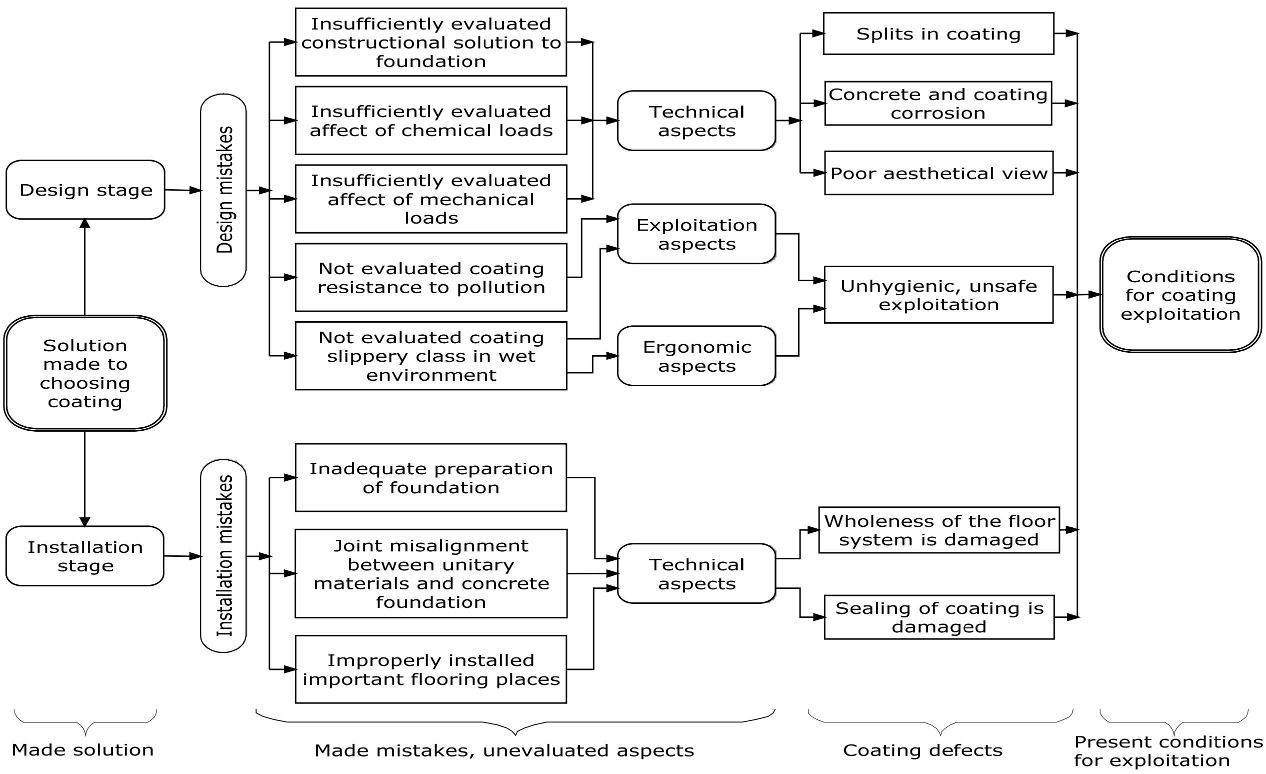

Fig. 5. The influence of mistakes making solutions at design and installation stage on conditions for coating exploitation

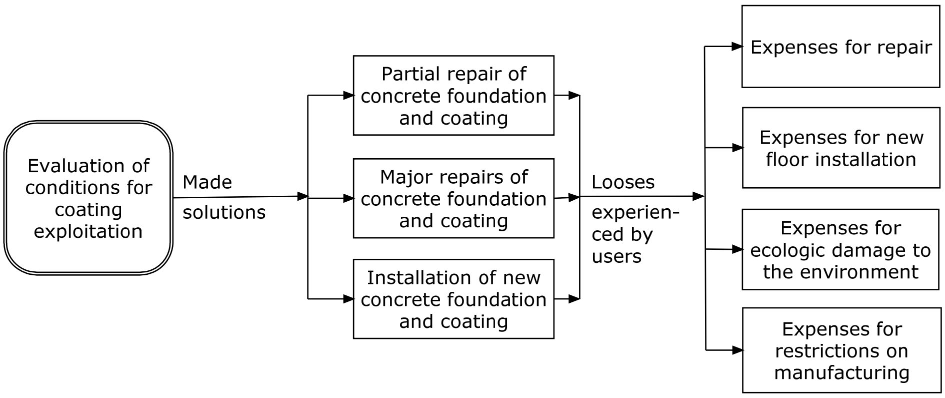

Fig. 6. The influence of making solutions to coating on the users (industrial companies)

concrete from aggressive chemical penetration into the concrete layer and later into the ground, thus becoming dangerous to soil and water pollution (Fig. 6).

4. Expedience and problems of solutions to coating design in terms of reliability

One of the ways to find an appropriate solution to the problem should be designing industrial concrete floors considering reliability theory methods.

In light of the methods of the reliability theory, close attention to the expedience of structure design is paid in the documents of European technology platform on industrial safety stating that "All industrial objects use their infrastructure where manufacturing is performed and vehicles and industrial equipment are exploited. Their proper design, manufacture and setting an exploitation cycle have to ensure that improvement in exploitation technologies promote the development of industrial safety and the growth of European industry competitiveness. In this case, it is very important to install new technologies that will help with improving industrial projects of the companies seeking for qualitative and safe exploitation of companies. Therefore, risk grounded design, material selection and stochastic prognosis of structure set are needed. Such research has to provide knowledge and methods that will allow evaluating the service period of the structures that may experience local and total decomposition" (http://www.industrialsafety-tp.org/).

The problems of the reliability of building structures are relevant in Lithuania and foreign countries and can be seen from the analyzed works by Lithuanian and foreign scientists where the reliability of building materials used in building structures is examined: these issues are investigated in scientific works by Kamaitis (2007a, b, 2009), Kuniewski and Noortwijk (2007), Melchers (2003). The questions of building structure reliability were discussed by Kudzys and Vaitkevičius (1995), Kliukas and Kudzys (2004), Venckevičius (2005), Užpolevičius (2002), Kala (2007), Kudzys (2005), Zhong and Zhao (2005). The methods for evaluating important structure reliability and durability were proposed by Užpolevičius (2002), Kuniewsky and Noortwijk (2007), Melchers (2003). Still, the evaluation of the floor and solutions to floor coating in terms of reliability is poorly presented in scientific works by Lithuanian and foreign authors.

Industrial concrete floors are not that responsible structure the deterioration of which would be dangerous for building stability or people's life. Nevertheless, with reference to the analysis of coating exploitation state, coating deterioration can cause large economical damage for the users and have an influence on the safe exploitation of industrial companies and the environment.

The design of floor concrete slab and coating according to the methods of the reliability theory allows evaluating the chosen solution at design stage, thus minimizing and giving a fault correction possibility before the solution is reached. At the same time, it would decrease losses that appear because of design mistakes (Fig. 5, 6).

In this case, the evaluation of the reliability of solutions worked out at installation stage is an important point as it does not allow making design corrections but significantly affects them and thus provides the possibility of making timely prognosis for defects to floor structure and minimal repair when coating tightness is not damaged and concrete corrosion is not started. This allows to reduce users' economical looses several times. The proposed evaluation levels of concrete floor reliability and their influence on the effectiveness of evaluation results are presented in Fig. 7.

A scheme of floor structure is made of the following main elements: soil foundation, concrete panel, reinforcement, top coating layer. Normally, it is stated in calculations that the system is in the limitary state if there is even one element in this state (Kudzys and Vaitkevičius 1995).

The analysis of floor coating condition, the factors that influence floor reliability and the system complex model of the factors influencing concrete floor reliability (Fig. 8) show that if the evaluation of the reliability of the coating and concrete structure panel is made separately, the whole floor structure system will not be reliable.

Despite of how well solutions for choosing floor coating design are analyzed and evaluated and how thoroughly installation technology is made, in case the quality of concrete structure is not high enough, it will not ensure the required reliability of working out a solution to selecting coating. Besides, a well performed solution to concrete foundation will not ensure the reliability of floor structure if the solution to coating is not effective and does not fulfill exploitation conditions. Respectively, the reliability of the floor structure system is influenced by

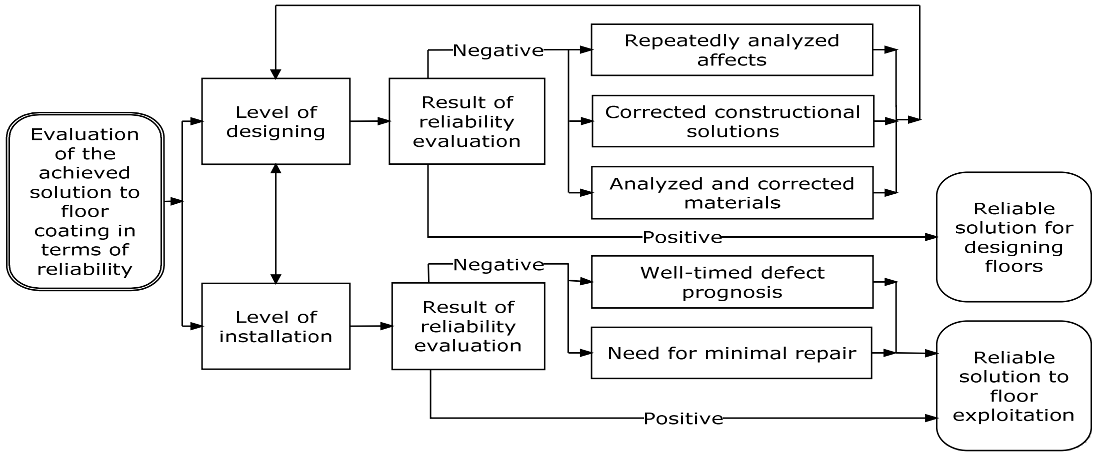

Fig. 7. The levels of evaluating the reliability of industrial concrete floors and the effectiveness of evaluation results

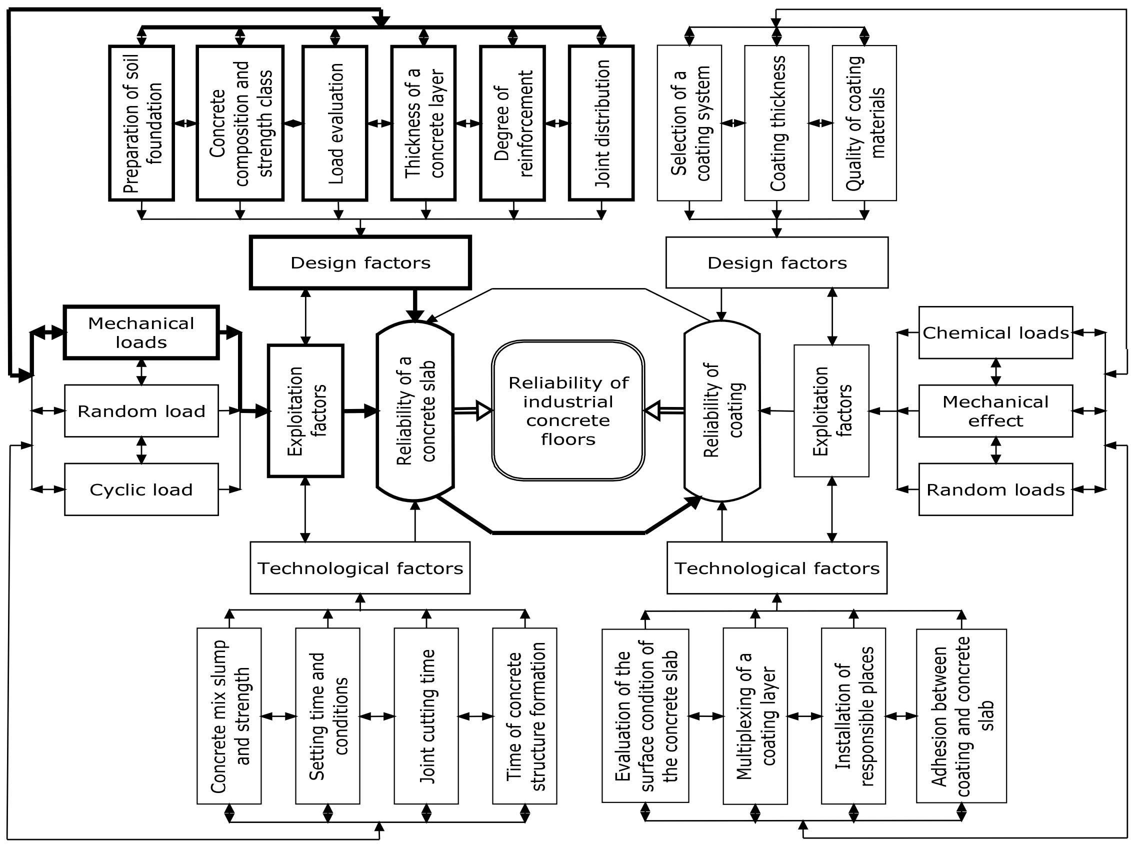

Fig. 8. A complex model of factors influencing the system of concrete floor reliability

solutions made considering soil foundation and reinforcement. It is possible to state that the reliability of the industrial concrete floor structure system is ensured when all the elements of the system are designed correctly, i. e. all factors that influence the reliability of the floor structure system are evaluated (Fig. 8).

All these factors are of different nature, including materials used for the elements of floor structure. Therefore, different methods can be designed, applied and used for calculating the reliability of an appropriate floor structure element in view of different factors.

The evaluation of floor structure is a very complicated process that requires in-depth experimental research, and therefore is rarely applied. As the prognosis of economists show, demand for industrial floors will grow in the future and the mistakes made to reach the required solution will rebound to users and will not help with solving environmental problems. Scientific research on the above mentioned problem must be the most challenging task for scientists in the nearest future.

Further in the article, a practical example of calculating the statistical reliability of the concrete slabs making a direct impact on coating reliability regarding acting mechanical loads in the meat cutting shop is presented. In this case, a precondition that other loads (random, cyclic) are not heavy enough and have no influence on reliability (Fig. 8) is made.

5. The theoretical elements of evaluating the reliability of the concrete floor slab designed in the meat cutting shop and evaluation of acting mechanical loads

Properly designed and qualitatively installed floor structure is usually reliable when its probable reliability rate P is close to one or 100%. In this case, probability Q that the cover during exploitation gets into the limitary state will be very low and near to 0 (Kudzys and Vaitkevičius 1995).

To calculate the reliability rates of floor structure, it is necessary to know the values of the probability distribution of composite element efficiency function Z = R-E in any accidental process or succession cut k or l: the arithmetic averages Z_{km} and Z_{lm} of function Z, dispersions s^2Z_k and s^2Z_l, its auto-covariation cov (Z_k and Z_l) and instantaneous element safety P_k {Z_k >0} (Kudzys and Vaitkevičius 1995).

Instantaneous safety is a conditional rate that describes probable element reliability in case the whole load is episodic or onetime (Kudzys and Vaitkevičius 1995). This reliability rate is calculated according to formula (1):

$$P_k\{z_k > 0\} = \int_0^{\infty} g_f(f) G_\sigma(\sigma) df. \qquad (1)$$

Formulas $g_f(f)$ and G_σ (σ) include element resistance f and its tension σ which are probable density and distribution functions respectively (Kruopis 1993, Kudzys and Vaitkevičius 1995).

To calculate the functions of material resistance, stress probability density and distribution as well as the instantaneous safety of an element, it is practical to make static and dynamic models (Kudzys and Vaitkevičius 1995).

The classified data on the meat cutting shop concrete floors is as follows: concrete strength class – C25/30, foundation elasticity module – 60 MPa, load values evaluating assurance factors according to STR 2.05.04:2003 (Table 1), designed concrete floor thickness – 130 mm. A load distribution scheme is shown in Fig. 9.

To evaluate the reliability of concrete floors, the following main stages are foreseen (Fig. 10).

Table 1. Calculated mechanical loads in the meat cutting shop

Load	Load type	Load size, kN
Meat cutting conveyor	Static, vertical, concentrated	18
Auto car	Dynamic, vertical, pivotal	102
Auto car	Dynamic, horizontal, pivotal	34.5
Work places (people, carts)	Dynamic, vertical, concentrated	1.8
Containers of cut meat	Static, vertical, concentrated	5

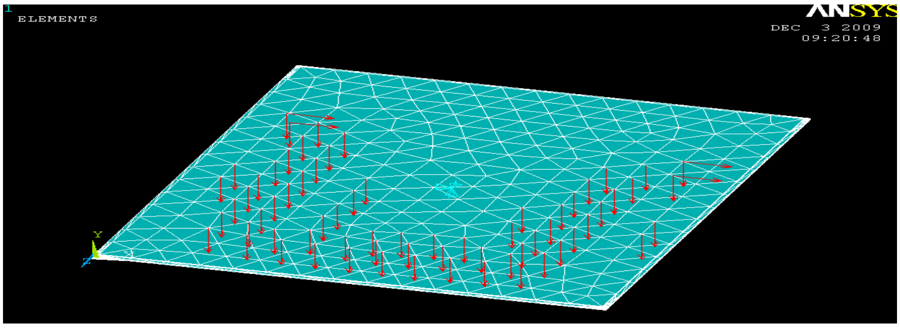

Fig. 9. A load distribution scheme in the meat cutting shop

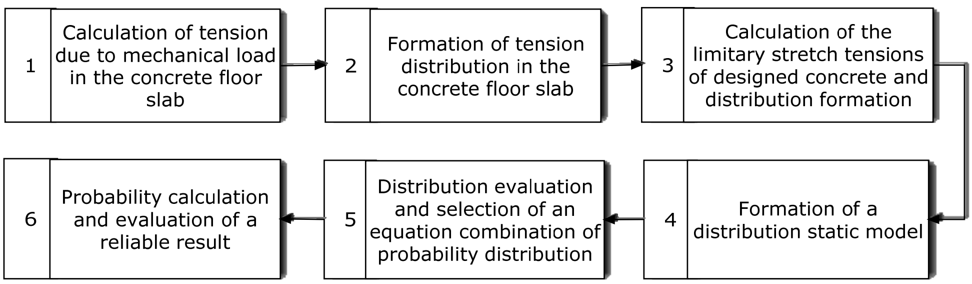

Fig. 10. Reliability evaluation stages of an industrial concrete slab

1. The calculation of tension due to mechanical load in a concrete floor slab installed on an elastic foundation is performed applying the limited element method and calculation programme ANSYS.

The algorithm of modeling and calculation is presented in Fig. 11.

The obtained results are presented in Figs. 12 and 13.

2. Using the obtained results, the histograms of tension value distribution are made and their statistical data are calculated (Figs. 14, 15).

3. To analyse the distribution of concrete strenght and to form probability distribution, data obtained in two factory laboratories were used testing the strength of concrete C25/30 within the period of one month (Fig. 16).

According to STR 2.05.05:2005, the calculated concrete strengths in compression and limitary stretch tensions are figured out and the probability distributions of the calculated concrete compression strength and limitary stretch tensions are formed indicating their statistics (Figs. 17 and 18).

4. Distributions show that concrete strength while compressing is sufficient. Probability that tensions in the concrete panel will exceed the designed concrete strength is equal to 0. Therefore, in this case, it is not advisable to form a static model. Analyzing the histograms of concrete strength in stretch, it can be noticed a case when maximal stretch tensions in the concrete slab due to mechanical loads will exceed the stretch tensions of designed concrete. This case is understood better when the static model is made. In this case, stretch tensions in the concrete slabs are distributed according to the lognormal law (Fig. 15) and strength tensions in designed concrete while stretching are distributed according to the normal law (Fig. 18). The made static model for calculating instantaneous element safety is shown in Fig. 19.

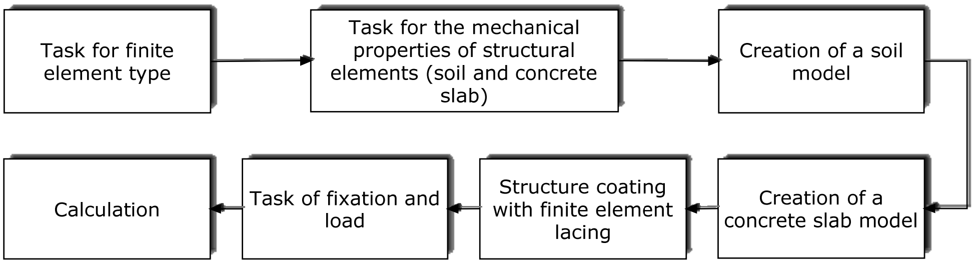

Fig. 11. The algorithm of slab modelling and calculation programme ANSYS

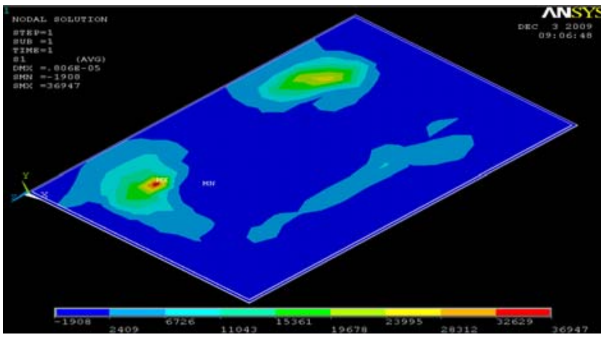

Fig. 12. The distribution of tensile stresses (σ_1) across the concrete slab

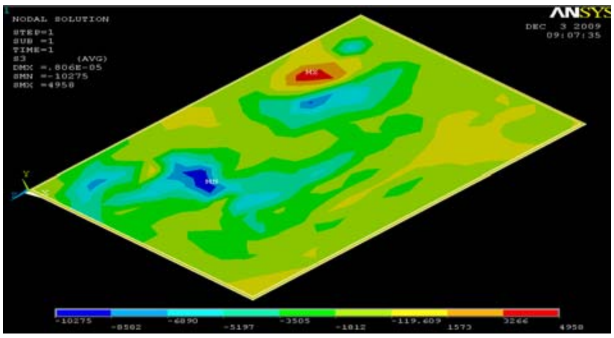

Fig. 13. The distribution of compression stresses (σ_3) across the concrete slab

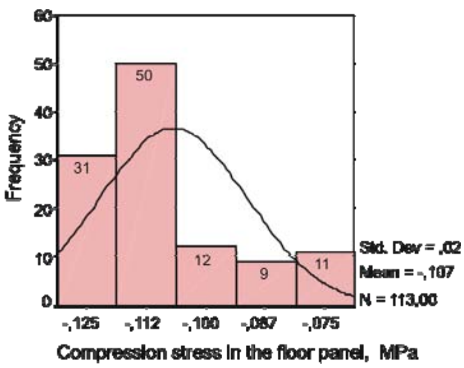

Fig. 14. A histogram of compression stress distribution in the floor slab affected by mechanical load

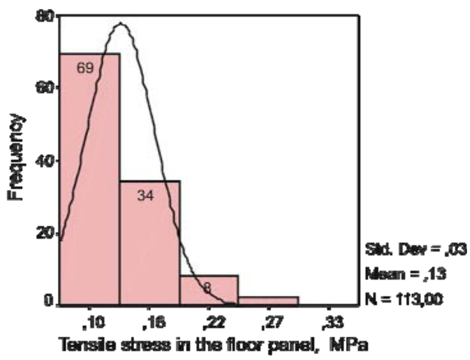

Fig. 15. A histogram of tensile stress distribution in the floor slab affected by mechanical load

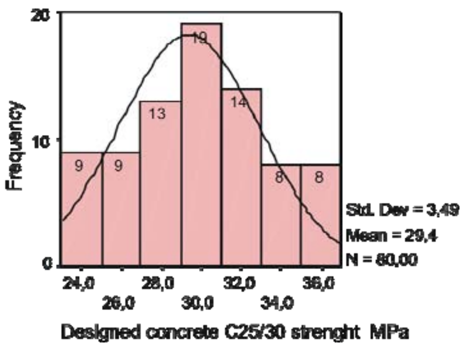

Fig. 16. A histogram of the strengh of designed concrete C25/30

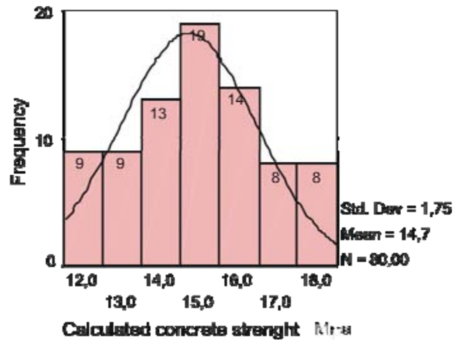

Fig. 17. A histogram of the calculated concrete strength

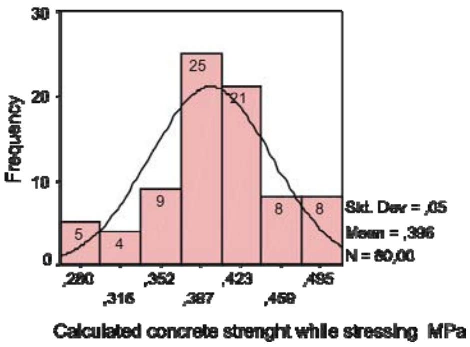

Fig. 18. A histogram of the calculated concrete strength while stressing

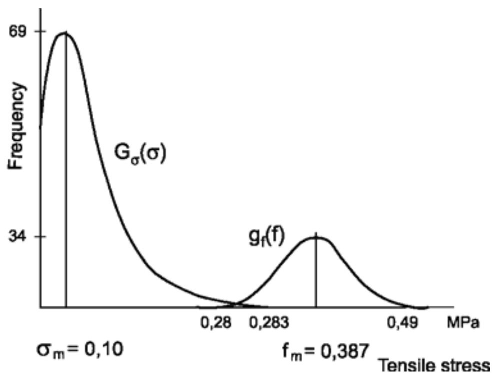

Fig. 19. A static model for calculating an instantaneous element safety factor when stresses in concrete slabs $G_\sigma(\sigma)$ are distributed according to the lognormal law and designed concrete strength $g_f(f)$ is distributed according to the normal law

5. In the analyzed case, tensions in concrete slab $G_\sigma(\sigma)$ are distributed according to the lognormal law and concrete strength $g_f(f)$ is distributed according to the normal law.

The function of normal distribution density is:

$$\varphi\left(X\middle|\mu,\sigma\right)=\frac{1}{\sqrt{2\pi\sigma}}exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\},\quad \sigma>0,$$

$$-\infty<\mu<\infty. \qquad (2)$$

Normal probability distribution is completely defined by average μ and dispersion σ^2 (Kruopis 1993).

The density of lognormal probability distribution has different forms. The interval of possible values is $(0, +\infty)$.

The distribution values of a lognormal random value are expressed by the values of function $\Phi(x)$:

$$P(X<x)=P\{Y<\ln x\}=\Phi((\ln x-\mu)/\sigma), \qquad (3)$$

where X – a random value the logarithm $Y = \ln X$ of which is distributed according to the normal law having parameters μ and σ^2 ((Kruopis 1993).

Using these values, the instantaneous safety of floor structure is calculated according to formula (1). The calculation of such an integral is rather complex. Therefore, for this purpose, MATLAB (*MATrix LABoratory*) software is used [$G_\sigma(\sigma)$ with parameters μ = 0.13 and σ^2 = 0.0009, $g_f(f)$ with parameters μ = 0.396 and σ^2 = 0,0025].

The reliability value is P_k (z_k > 0) = 0.99952 or 99.952%.

When the instantaneous safety of floor structure is known, reliability index β is set using statistical tables (statistics Φ(x)) (Kruopis 1993). In this case, β = 3.3 = 3.3 STR 2.05.03:2003 when reliability class is RC1). The structure reliability index shows that the reliability of the mechanical load of concrete floors in the meat cutting shop is sufficient and the worked out solution is acceptable.

6. Conclusions

1. The problems analyzed in Lithuanian and foreign scientific sources show that making solutions for choosing industrial concrete floor coating is a difficult and very responsible process that requires a detailed complex multivariate analysis of the reached solution. Such analysis also has need for examining solutions considering technical, operational, technological and requiring special conditions aspects along with equally important economic, ergonomic, environment protection, ecologic, aesthetic etc. features. The system is very complicated, thus it is difficult to make a correct and effective design and technological solution.

2. Mistakes in concrete floor coating design and technological solutions cause large economical damage for industrial floor users. The damage can be evaluated as the expenses floor repair, reconstruction or new floor installation, loss that companies experience due to the stopped or terminated manufacturing processes for floor

repair or change, and the expenses of compensating the damage made for the environment.

3. The performed exploitation analysis of industrial floors has revealed that the system of choosing an appropriate solution to floor coating is complicated, and therefore a number of mistakes are made at design and technological stages. The results of discovered mistakes directly affect floor and coating condition at an exploitation stage: coatings do not function normally because of cracks – concrete is not protected from harmful environment factors and therefore begins to corrode and becomes inapplicable to exploit. When coating and concrete slabs are leaky, pollution from manufacturing departments gets into the environment and aggressive liquids polluting soil and water damage an ecological environment. Coating designed in a wet environment is risky for a safe working environment. Coatings chosen for dirty surfaces are dangerous for hygiene inside the building.

4. The analysis of foreign and Lithuanian scientific sources also indicates that the problems of floor coating design and the forecasting issues dealing with the effectiveness of technological solutions are inefficiently analyzed in light of a scientific aspect. Statistical data and assessment of economic development trends for the following ten years have revealed that large areas of concrete floors are and will be installed in the process of renovating companies. Paying no attention to the scientific analysis of making solutions for choosing floor and floor coating can cause unsatisfactory outcomes for economic company's efficiency and environmental ecology.

5. The evaluation of solutions made for choosing industrial floors in terms of reliability allows minimizing designers' mistakes as in case the result is unacceptable, it may be corrected before implementing the worked out solution until the desirable result is obtained. The evaluation of technological solutions taking into account reliability allows foreseeing possible defects eliminating them on time when the expenses of simple repair are several times lower.

6. The practical task evaluates the reliability of the designed floor concrete slabs considering mechanical load which makes 99.952%. Possibility that the stretch tensions of the concrete floor slabs taking into consideration load will exceed the limitary stretch tensions of concrete C25/30 is equal to 0.00048. On the basis of calculation results, it can be stated that the reliability of the mechanical loads of the floor concrete slabs in the meat cutting shop floors (floor thickness is 30mm and using concrete C 25/30 for installation) is sufficient and does not exceed standard requirements. However, in order to increase the rate of the designed concrete strength while stretching, a possibility of reinforcing the concrete used for the floor concrete slabs with a metal fibre arises which is not necessary in the analyzed case.

References

Aguiar, J. B.; Camões, A.; Moreira, P. M. 2008. Performance of concrete in aggressive environment, *Journal of Concrete Structures and Materials* 2(1): 21–25. doi:10.4334/IJCSM.2008.2.1.021

Aguiar, J. B.; Camões, A.; Moreira, P. M. 2008. Coatings for concrete protection against aggressive environments, *Journal of Advanced Concrete Technology* 6(1): 243–250. doi:10.3151/jact.6.243

Aguiar, J.; Moreira, P.; Lukowsky, P.; Czarnecki, L.; Camoes, A.; Van Gemert, D. 2007. Ranking procedure for polymeric coatings and hydrophobic agents for concrete protection, *International Journal for Restoration of Buildings and Monuments* 13(4): 251–264.

Almusallam, A.; Khan, F. M.; Maslehuddin, M. 2002. Performance of concrete coatings under varying exposure conditions, *Journal of Materials and Structures* 35: 487–494. doi:10.1007/BF02483136

Cham, R.; Redfern, M. S. 2001. Effect of flooring on standing comfort and fatigue, *Hum. Factors* 43(3): 381–391 (Department of Bioengineering, University of Pittsburgh, Pennsylvania). doi:10.1518/001872001775898205

Czarnecki, L.; Garbacz, A.; Krystosiak, M. 2006. On the ultrasonic assessment of adhesion between polymer coating and concrete substrate Non-Destructive Testing, *Journal of Cement and Concrete Composites* 28(4): 360–369. doi:10.1016/j.cemconcomp.2006.02.017

Dallons, J. L. Hu*midity Tolerant Primer for Floor Coating*, Cardolite Corporation, Newark, USA (NJ). Available from Internet: <http://www.cardolite.com/Pdf/HumidityTolerantPrimerforFloorCoating.pdf>.

Figovsky, O.; Shapovalov, L.; Beilin, D. *Monolithic flooring based on nonisocyanate polyurethane binder*. Available from Internet: <http://www.vgtu.lt/leidiniai/leidykla/MBM_2007/1pdf/Figovski_shap.pdf>.

Fitzsimons, B.; Parry, T. 2009. Paint and coating failures and defects, *Shreir's Corrosion* 4: 2728–2745.

Frigione, M.; Aiello, M. A.; Naddeo, C. 2006. Water effects on the bond strength of concrete/concrete adhesive joint, *Journal of Construction and Building Materials* 20(10): 957–970. doi:10.1016/j.conbuildmat.2005.06.015

Garber, G. 2006 *Design and construction of concrete floors*. 2 ed. 384 p.

Jayson, L.; Helsel, P. E. 2007. KTA-Tator, Inc. Some hard truths on concrete coatings and coverings, *Journal of Architectural Coatings* 3(1): 70–71.

Kala, Z. 2007. Influence of partial safety factors on design reliability of steel structures – probability and fuzzy probability assessments, *Journal of Civil Engineering and Management* 13(4): 291–296.

Kamaitis, Z. 2007a. Structural design of polymer protective coatings for reinforced concrete structures. Part I: theoretical considerations, *Journal of Civil Engineering and Management* 13(1): 11–17.

Kamaitis, Z. 2007b. Structural design of polymer protective coatings for reinforced concrete structures. Part II: experimental verification, *Journal of Civil Engineering and Management* 13(1): 19–26.

Kamaitis, Z. 2009. Modeling of corrosion protection as standby system for coated reinforced concrete structures, *Journal of Civil Engineering and Management* 15(4): 387–394. doi:10.3846/1392-3730.2009.15.387-394

Kliukas, R.; Kudzys, A. 2004. Probabilistic durability prediction of existing building elements, *Journal of Civil Engineering and Management* 10(2): 107–112.

Kotnarowska, D. 2008. Influence of mechanical factors on surface state of acrylic coatings with nanofillers, *Journal of Materials Science* 14(4): 337–341.

Krell, J. 2007. Oberflache und Nachbehandlung von Betonboden, in *Symposium Baustoffe und Bauwerkserhaltung*, Universitat Karlsruhe (TH). 63.

Kruopis, J. 1993. *Matematinė statistika* [Mathematical statistics]. Vilnius: Mokslo ir enciklopedijų leidykla. 416 p.

Kudzys, A. 2005. Survival probability of existing structures, *Mechanika* (2): 42–46.

Kudzys, A.; Vaitkevičius, V. 1995. *Estimation of safety and durability of welded and jointless steel structures.* Vilnius: Solertijos leidykla. 131 p.

Kuisma, R.; Kymäläinen, H. R.; Sjöberg, A. M. 2009. Determination of cleanability and wearing of plastic flooring surfaces in field and laboratory conditions, *Journal of Construction and Building Materials* 23(2): 1093–1101. doi:10.1016/j.conbuildmat.2008.05.020

Kuniewski, S. P.; van Noortwijk, J. M. 2007. Sampling inspection for the evaluation of time-dependent reliability of deteriorating structures, in *Risk, Reliability and Societal Safety in 16th European Safety and Reliability Conference (ESREL 2007) in Stavanger, Norway, June 2007*, 281–288.

Lang, G. 2003. Zementgebundene, einkomponentige, selbstverlaufende Beschichtungen, in *Tagungsband Industrieböden 2003: 3, Internationales Kolloquium Industrieböden*, Technische Akademie Esslingen –TAE, 851–857.

Lietuvos ekonomikos augimo ir konkurencingumo šaltinių (veiksnių) kompleksinė studija [Complex study of Lithuanian economy growth and competitive ability sources (factors)]. 2006. KTU.

Lietuvos ūkio (ekonomikos) plėtros iki 2015 metų ilgalaikės strategijos atnaujinimas. 2007 [Update of long-term economic development strategy of Lithuania until 2015]. Lithuanian Academy of Science.

Lohmeyer, G. 2006. *Industrieboden für sensible Produktionsbereiche*. MM, Wurzburg. 17 S.

Lohmeyer, G.; Ebeling, K. 2008. *Betonböden für Produktions- und Lagerhallen. Planung, Bemessung, Ausführung.* Bundesverband der Deutschen Zementindustrie, Köln. 393 S.

Medeiros, M. H. F.; Helene, P. 2009. Surface treatment of reinforced concrete in marine environment: Influence on chloride diffusion coefficient and capillary water absorption, *Journal of Construction and Building Materials* 23(3): 1476–1484. doi:10.1016/j.conbuildmat.2008.06.013

Melchers, R. E. 2003. Probabilistic model for marine corrosion of steel for structural reliability assessment, *Journal of Structural Engineering* 129(11): 1484–1493. doi:10.1061/(ASCE)0733-9445(2003)129:11(1484)

Moreira, P. M.; Aguiar, J. B.; Camões, A. 2006. Systems for superficial protection of concretes, in *International Symposium Polymers in Concrete*, 225–249.

Perspektiven der europäischen Baukonjunktur. Tagungsband zur „Bautec-2010“. RKW Rationalisierungsgemeinschaft. 34 S.

Rufo, M.; Raymond, W.; Monaghan, S. 2007. 2K Waterborne Epoxy Coatings, *Journal Air Products and Chemicals*, Inc.: 1–11. Available from Internet: <http://www.airproducts.com/NR/rdonlyres/5E27B3A0-81D4-49EB-A1CB-98B4F274AF1B/0/technical_paper_2Kwaterborne_epoxy.pdf>.

Schuhmann, H. 2005. *Kunstharzbeläge. Mängelfreie Ausführung und bauphysikalische Grundlagen*. Fraunhofer IRB Verlag. 147 S.

Seidler, P. 2007. Interview, in *6-te Internationale Kolloquium Industrieböden. Stutgart*. Available from Internet: <http://www.astradur.de/presse_bwd.htm>.

Statistics Lithuania. 2009. *Annual building construction data* [Online]. Department of Statistics to the Government of the Republic of Lithuania, Vilnius [accessed 16 January 2010]. Available from Internet: <http://www.stat.gov.lt/lt/pages/view/?id=2441>.

STR 2.05.03. 2003. *Statybinių konstrukcijų projektavimo pagrindai* [Basics of building construction design]. Vilnius: Ministry of Environment of the Republic of Lithuania.

STR 2.05.04. 2003. *Poveikiai ir apkrovos* [Impacts and loads]. Vilnius: Ministry of Environment of the Republic of Lithuania.

STR 2.05.05. 2005. *Betoninių ir gelžbetoninių konstrukcijų projektavimas* [Design of concrete and reinforced concrete structures]. Vilnius: Ministry of Environment of the Republic of Lithuania.

Užpolevičius, B. 2002. Probabilistic-statistical design method for limit state damage prevention, *Journal of Civil Engineering and Management* 8(Suppl. 1): 44–51.

Venckevičius, V. 2005. About the calculation of concrete elements subjected to local compression, *Journal of Civil Engineering and Management* 11(3): 243–248.

Wagner, J. P.; Reichertz, A. 2007. Ausführung-Einbauplanung und Technik sowie neue Erkenntnisse für Oberflächenbearbeitung bei LP- Betonen, in *Symposium Baustoffe und Bauwerkserhaltung*, Universitat Karlsruhe (TH), 11–57.

White, B.; Jordan, J. L; Richards, D.; W. Spowart, J. E.; Thadhani, N. N. 2009. *Microstructural Design & Optimization of Highly Filled Epoxy Based Composites***:** Final Report for Period 5 May 2006 –30 September 2009. School of Material Science & Engineering Georgia Institute of Technology, Atlanta, 45.

Wiegrink, K. H. 2007. Planung und Ausschreibung von Betonboden, in *Symposium Baustoffe und Bauwerkserhaltung*, Universität Karlsruhe (TH), 11.

Wolff, L. 2009. *Mechanismen der Blasenbildung bei Reaktionsharzbeschichtungen auf Beton. Deutscher Ausschuss für Stahlbeton*, DAfStb, Berlin. 178 S.

Zeleniakienė, D.; Kleveckas, T.; Liukaitis, J**.** 2005. The effect of loading direction and pores distribution mode on porous polymer material stress concentration, *Journal of Materials Science* 11(2): 123–128.

Zhong, W. Q.; Zhao, Y. G**.** 2005. Reliability bound estimation for R.C. structures under corrosive effects, in *Collaboration and Harmonization in Creative Systems*. London, 755–761.

Žiogas, V.; Juočiūnas, S.; Medelienė, V. 2008. Analysis of reliability of installation monolithic concrete floors and their covering, in *Proceedings of International Conference Advanced Construction*, 13–14 November, Kaunas, Lithuania, 347–354.

PRAMONINIŲ BETONINIŲ GRINDŲ DANGŲ SPRENDIMŲ PRIĖMIMAS IR PATIKIMUMO ĮVERTINIMO TIKSLINGUMAS

V. Medelienė, V. A. Žiogas

S a n t r a u k a

Spartėjant ekonominiam ūkio vystymuisi ir plečiantis pramonei per pastaruosius metus Lietuvoje smarkiai išaugo ir ateityje turi tendenciją augti pramoninių betoninių grindų poreikis. Šios grindys dėl įvairiai modifikuojamo betono ir gausaus skirtingų dangų medžiagų pasirinkimo šiuo metu naudojamos beveik visose pramonės įmonėse. Esant gausiai įvairių dangų medžiagų pasiūlai, tobulėjant technologiniams sprendimams, griežtinant ekologinius, ergonominius reikalavimus, priimti efektyvų dangos sprendimą vis sunkiau. Šiame straipsnyje nagrinėjamos sudėtingos dangų sprendimų priėmimo problemos, pateikiamas eksploatacinės dangų būklės įvertinimas, analizuojamos daromos klaidos ir ekonominės padarytų klaidų pasekmės grindis naudojančioms įmonėms. Nagrinėjamas tikslingumas ir problematika priimtų grindų sprendimų vertinimo patikimumo aspektu, pateikiamas sudarytas patikimumą veikiančių veiksnių kompleksinis modelis bei praktinis statistinio patikimumo skaičiavimo pavyzdys.

Reikšminiai žodžiai: dangų sprendimų vertinimo aspektai, sprendimų priėmimo klaidos, patikimumo vertinimo lygmenys, patikimumą veikiančių veiksnių kompleksinis modelis, statistinis patikimumas.

Violeta MEDELIENĖ. Department of Civil Engineering Technologies MSc (2001, civil engineer) at Kaunas University of Technology. Research interests: industrial concrete floor coating systems, installation technologies, evaluation of engineering solutions.

Vigantas Antanas ŽIOGAS. Doctor, Associate Professor. Dept of Civil Engineering Technologies. Assoc Prof (1996) at Kaunas University of Technology. Research interests: massive monolithic building technologies, monolithic concrete floors arranging technologies, repair and strengthening technologies of concrete and reinforced concrete buildings. Design of concrete mixes by special requirements, improvement the monolithic building technologies, research on special building technologies. He is a member of editorial board of journal Engineering Structures and Technologies.