ISSN 1392–3730
JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT
http:/www.jcem.vgtu.lt
2005, Vol XI, No 2, 153–162

DESIGN AND INSTALLATION PECULIARITIES OF MONOLITHIC CONCRETE FLOOR

Vigantas Žiogas, Svajūnas Jučiūnas

Dept of Civil Engineering Technologies, Kaunas University of Technology, Studentų g. 48, LT-51367, Kaunas, Lithuania. E-mail: vigantas.ziogas@ktu.lt; svajunas.juociunas@ktu.lt

Received 21 Dec 2004; accepted 12 Apr 2005

Abstract. Monolithic concrete floors are frequently designed as plain concrete slabs. The purpose of the plain concrete floor is to transmit loading from its source to the subgrade with minimal distress. The magnitude of these stresses depends on factors such as the subgrade strength, solution of construction, the quality of construction, the magnitude and character of loads. Here is presented the joint spacing for various construction solutions of concrete floor. In practice, joint spacing should be corrected by evaluating rheological properties of concrete mix, type of aggregate, its volumetric concentration and impurity. The direct expenditures of main construction layers were investigated and used for optimization the technologies installation of monolithic concrete floors. The initial data for evaluating the multiple criteria were calculated by estimating the real and practical characteristics, which are represented in this paper. Multiple criteria complex proportional evaluation is used to find a rational decision installation of monolithic concrete floors.

Keywords: monolithic concrete floor, design, thickness of floor, joint spacing, reinforcement, installation, direct expenditures, multiple criteria estimation.

1. Introduction

Monolithic concrete floor design, installation technologies, employment of proper materials and construction selection are interrelated, therefore floor installation solution requires a detailed analysis. Floor efficiency and quality are conditioned by proper application of normative requirements, use of proper building materials, optimal concrete mix and cover, also by selection of advanced installation technologies and qualified constructors. The relation of such processes is given in figure 1 [1].

Strength of experience of foreign countries, monolithic concrete floor design and floor service depend on the following factors:

1) thickness of floor and its subgrade strength;
2) type of joint and their spacing;
3) load transfer across joints and cracks [2].

Thickness of floor depends on the character and type of load, modulus of subgrade and concrete flexural strength. In many countries these factors are measured in floor thickness calculation methods (ACI, BCA, SWE) [3–5]. However, our previous analysis [6] of methods indicated that these methods do not include calculations of other important factors, which influence thickness of floor: grade and type of reinforcement and joint spacing.

For selecting alternatives of monolithic concrete floor installation technologies, the main quantitative characteristics must be considered, ie an evaluation criteria system must be made. The system must contain quantitative and qualitative indexes – load, class of concrete, thickness of floor, modulus of subgrade, etc. Therefore a rational solution of concrete floor installation is a complex task containing many criteria. Thus various solution methods, which are substantiated by theories of statistic distribution, utility and game theory, are used. In practice, all building process solutions are divided into the following stages: formation of alternative variants of matrix, its normalisation and estimation of rational variants. With reference to given methods [7] and author's [8] analysis, the formed matrix normalisation stage is very important, because its selection does not only influence the final decision, but also virtually changes the distribution of priorities' alternative variants and the final decision.

This article investigates the influence of alternative monolithic concrete floor installation variants' indexes on other criteria of floor constructions' solution. Therefore it is necessary to evaluate and calculate all alterations' influence on the final results of evaluations. Thus it is purposeful to apply the complex proportion method. According to this method, the variants' priority of researched floor installation is estimated, which directly and proportionally depends on the criteria system, characterising alternative decisions.

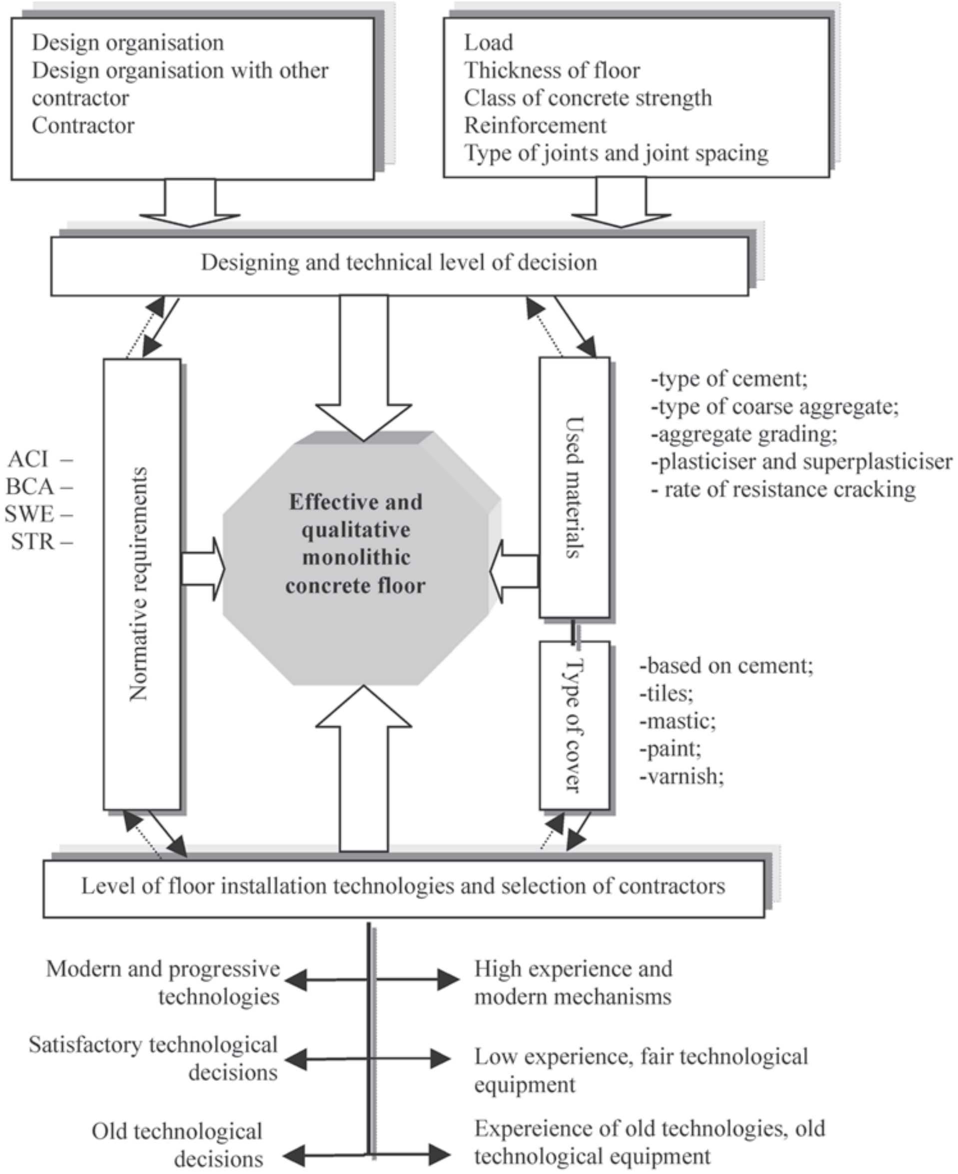

Fig 1. Scheme of effective and qualitative monolithic concrete floor design and installation

2. Design aspects for estimation of concrete floor thickness

Design of monolithic concrete floor involves the interaction of the floor and soil support system to resist moments and shears induced by the applied loads. Therefore, the properties of both the concrete and the soil are important.

One of the most important considerations, when concrete floor is designed, is the strength of the subgrade and subbase. It influences the thickness of floor and determines to degree how well the floor will perform. Proper evaluations of subgrades and the design and construction of subbases are critical to the structural performance and the quality of concrete floor.

The modulus of subgrade reaction *(k)* is used to evaluate both subgrade and subbase support. American recommendations tend to determine the subgrade strength from Table 1 in terms of k, which is typically sufficient for design analysis [9].

The subgrade must be compacted to the required density and a well-graded gravel of the subbase layer must be spread over the entire subgrade in order to form a more uniform support for the slab. It should be com-

Table 1. Subgrade soil types and approximate k values

Type of soil	Support	k values range, kPa/mm
Fine-grained soils in which silt and clay-size particles	Low	30–48
Sands and sand-gravel mixtures amounts of silt and clay	Medium	52–68
Sands and sand-gravel mixtures	High	72–88

pacted to a minimum 98 % of maximum density at optimum moisture content [3].

The subgrade and subbase modulus of elasticity depending on loads are shown in Table 2 [9].

Table 2. Subgrade and subbase modulus of elasticity (according to German recommendation)

Max concentrated load, kN	Subgrade modulus of elasticity, MPa	Subbase modulus of elasticity, MPa
≤ 32,5	≥ 30	≥ 80
≤ 60	≥ 45	≥ 100
≤ 100	≥ 60	≥ 120
≤ 150	≥ 80	≥ 150
≤ 200	≥ 100	≥ 180

According to German recommendation, the ratio of subbase modulus of elasticity with modulus elasticity of subgrade must not exceed 2,5 [10].

In this paper we have applied the method of Portland Cement Association, establishing the thickness of plain concrete floor in earlier [6] research. According to this method, the thickness of these floors was established depending on different axle load (25–150 kN) and concrete class. Thickness of the floor can be decreased by 20 % using concrete of upper class for installing plain monolithic concrete floor.

The design procedure for reinforced concrete floor uses the principle of allowing a reduction in the required thickness of plain concrete floor due to the presence of steel reinforcement. The design method consists in determining the percentage of steel required, the thickness of reinforced floor, and the maximum allowable length (joint spacing) of the floor. Evaluating the thickness of reinforced floor is necessary first to calculate the required thickness of plain concrete floor (Fig 2). Thickness of reinforced floor was determined by the diagram, presented in a technical manual [11].

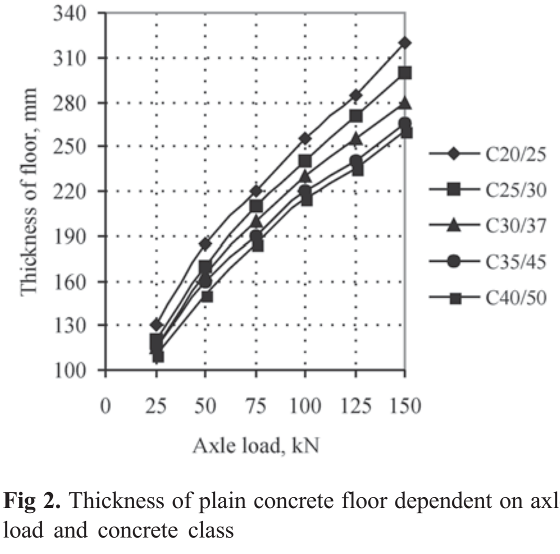

Fig 2. Thickness of plain concrete floor dependent on axle load and concrete class

The required thickness of steel fibre (50 mm length) for reinforced concrete floor was estimated by the diagram presented in a technical manual [11].

The results of calculation of thickness reinforced and steel fibre reinforced concrete floor are shown in Figs 3, 4. They show that the thickness of concrete floor increases, when the axle loads rise.

3. Reinforcing and joint spacing of monolithic concrete floor

There are three purposes of reinforcing monolithic concrete floor. These consist in shrinkage control, temperature control and addressing moment capacity. The welded wire provides a means for controlling the width of shrinkage cracks even with a relatively small percentage of steel.

The amount of steel (Fig 5) is calculated by equation [2, 12]:

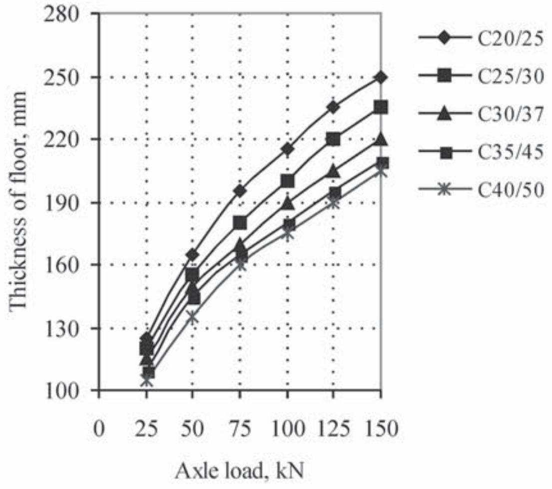

Fig 3. Thickness of reinforced concrete floor dependent on axle load and concrete class

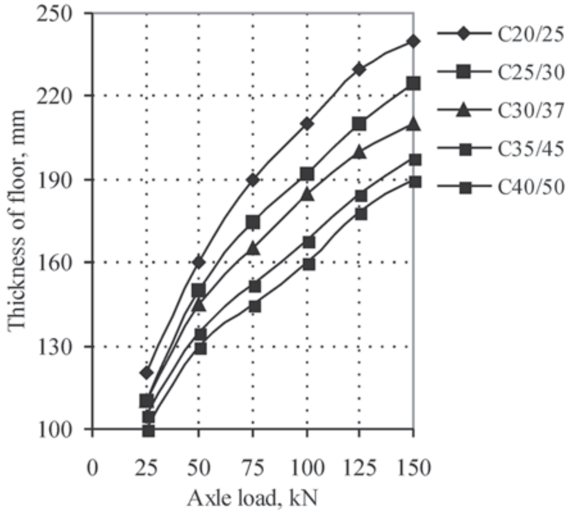

Fig 4. Thickness of steel fibre concrete floor dependent on axle load and concrete class

$$A_s = \frac{FLW}{2 \cdot f_s}, \quad (1)$$

where A_s – cross-sectional area (in cm^2) of steel per lineal metre of floor width; f_s – allowable stress in reinforcement, MPa; F – friction factor (this value ranges from 1,5 to 2); L – distance between joints (m); W – dead weight of the slab, kg/m^2.

This formula is frequently used to calculate the amount of reinforcement to serve as shrinkage and temperature reinforcement and to control crack widths for monolithic concrete floor. The reinforcement selected by this equation is not intended to serve as flexural reinforcement [12].

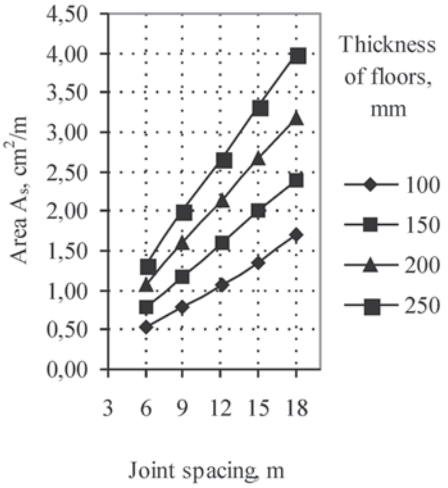

Fig 5. Reinforcement for concrete floor

The reinforcing prevents spalling or faulting at the cracks and provides a serviceable floor.

To be effective in controlling cracks, the steel mesh must be positioned at or above the middle depth of the floor. Distributed steel placed in floor for crack control does not increase significantly the load capacity of floor.

The location of steel is critical to both concrete floor behaviour and internal concrete stress. ACI recommends to place reinforcement 50 mm below the slab surface or at 1/3 the floor depth below surface. Caution should be taken when smaller percentages of reinforcement are used, because a lighter gage material may be more difficult to position and maintain in the top portion of floor [2].

For minimising cracking, steel fibres are used to increase shear strength, flexural fatigue, toughness endurance, and impact resistance in floor. The increases in mechanical properties depend primarily on the type and amount of steel fibre used in reduced floor thickness and increased contraction joint spacing. According to [13], flexural strength of steel fibre of reinforced concrete is formulated by the following formula:

$$f_d = \left(0{,}77 \cdot \sqrt{f_c^{'}}\right) \cdot \left(1 + \frac{R_{e3}}{100}\right), \quad (2)$$

where f_d – flexural strength, MPa; $f_c^{'}$ – compressive strength of concrete, MPa; R_{e3} – equivalent flexural ratio, %.

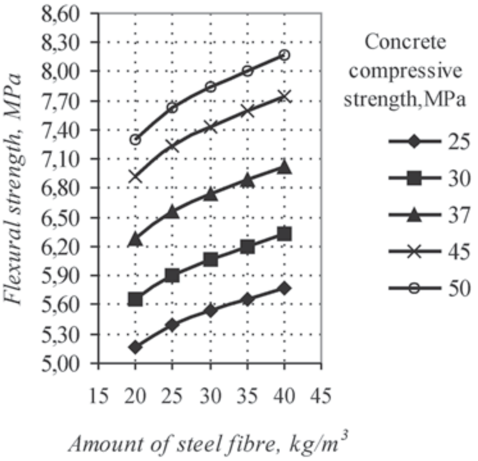

Fig 6. Flexural strength dependence on the amount of steel fibre

In the analysis, usable monolithic floor installation concrete classes are selected and steel fibre quantity is calculated. Research results are depicted in Fig 6. The figure indicates that when steel fibre quantity increases from 20 to 40 kg/m^3, flexural concrete strength will be increased by some 12 % in the same concrete class, and in the adjacent concrete class the flexural strength varies from 9,5 to 11 %.

The depicted formula (2) does not include the evaluated steel fibre length and diameter proportion. According to experimental data [14], influence of such steel fibre technical characteristics on equivalent flexural strength is depicted in Fig 7.

When length and diameter ratio (l/d) increase, the quantity of steel fibre in concrete mix may be decreased by about 17-50 % (Fig 7).

In the presented Figs 6, 7, the floor strength characteristics are examined when short-term loadings have an

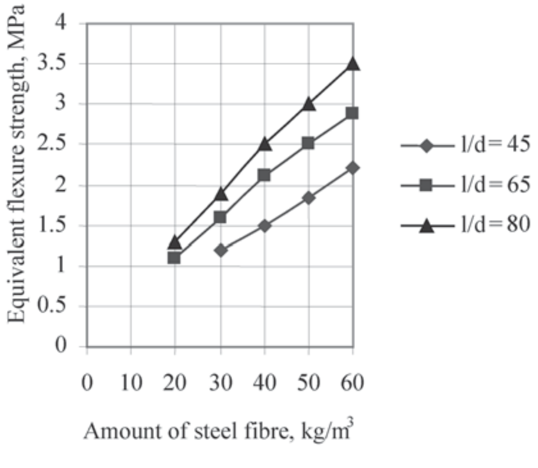

Fig 7. Equivalent flexural strength dependence on the amount of steel fibre and aspect ratio (l/d)

effect on it. At the time of service, monolithic concrete floor is affected by a long-term loading. For that purpose referring to [15] author made experiment analysis and expressed dependency upon the influence of various types of steel fibre to strain ratio when cyclic loading have an effect was determined. Strain ratio is formulated according to the following formula:

$$n_s = 1{,}0259 + 0{,}0764 \cdot V_f \frac{l_f}{d_f} - 0{,}0654 \cdot \log N \,, \qquad (3)$$

where n_s – stress ratio; V_f – amount of steel fibre, %; l_f / d_f – aspect ratio; N – number of fatigue cycles ($N = 10^6$).

In this analysis steel fibre used in monolithic concrete floor was chosen from various firms (“Dramix”, “Xarex”, “Korofibre” and “Fytek”). The presented chart (Table 3) shows that the length of steel fibre varied from 30 to 60 mm, proportion of the length and diameter (l/d) was 45–80, while fibre quantity varied from 25 to 78 kg/m^3 (0,25–1 %).

The research (Table 3) indicates that steel fibre ratio l/d slightly influences strain ratio n$_s$, which amounts to 1,5 %. When steel fibre quantity increases from 0,25 % to 1 %, strain ratio will increase about 6 %. Therefore one kind of steel fibre can be changed by another one under trade conditions, without much influence on floor performance.

Table 3. Relation of fatigue strength stress ratio an l_f / d_f of steel reinforced concrete

Amount of steel fibre V_f, %	Steel fibre length l_f, mm	Steel fibre diameter d_f, mm	$\frac{l_f}{d_f}$	Stress ratio, n
0,25	30	0,5	60	0,64
0,5				0,66
0,75				0,67
1				0,68
0,25	45	1	45	0,64
0,5				0,65
0,75				0,66
1				0,67
0,25	50	1	50	0,64
0,5				0,65
0,75				0,66
1				0,67
0,25	50	0,8	62	0,65
0,5				0,66
0,75				0,67
1				0,68
0,25	60	0,75	80	0,65
0,5				0,66
0,75				0,68
1				0,69
0,25	60	0,92	65	0,65
0,5				0,66
0,75				0,67
1				0,68

Joints of monolithic concrete floor are provided to:

- permit contraction and expansion of the concrete resulting from temperature and moisture changes;
- relieve warping and curling stresses due to temperature and moisture differentials;
- prevent irregular breaking of the floor slab; as a construction expedient;
- separate sections or strips of concrete placed at different times;
- isolate the floor slab from other building components.

There are four types of joints: contraction, construction, isolation and expansion [16].

Contraction joints are intended to create weakened planes in the concrete and regulate the location where cracks, resulting from dimensional changes, will occur.

Construction joints are typically placed at the end of a day’s work but may be required when concrete placement is stopped for longer than the initial setting time of concrete. In slabs they may be designed to permit movement or to transfer load. The location of construction joints should be planned. It may be desirable to achieve bond and continue reinforcement through a construction joint.

Isolation and expansion joints isolate or separate slabs from other parts of the structure, such as walls, footings or columns. They permit independent vertical and horizontal movement between adjoining parts of the structure and help minimise cracking when such movements are restrained.

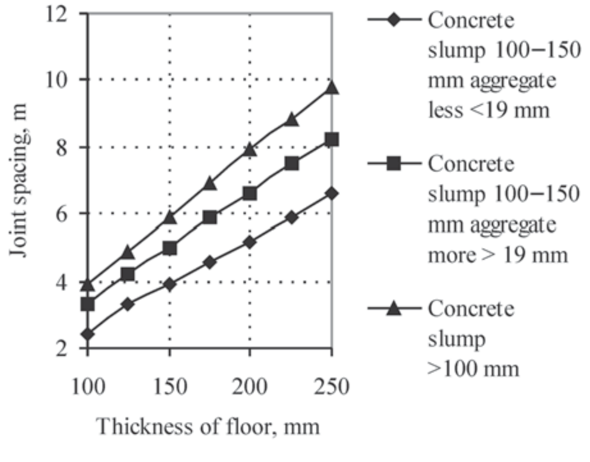

Fig 8. Joint spacing of plain concrete floor

Joints must be carefully designed and properly constructed if uncontrolled cracking of concrete flatwork is avoided. The American standard recommended to use joint spacing for plain concrete floor shown in Fig 8 [3].

Recommended maximum joint spacing of steel fibre reinforced floor is shown in Table 4. Additionally, the spacing between joints should not exceed about of 50 times the floor thickness [12].

Table 4. Recommended joint spacing of fibre reinforced concrete floor

Dosage rate, kg/m^3	20	25	30	35	40
Maximum joint spacing	6	7	8	10	12

Joint spacing is presented in Figs 5, 8 and Table 4. Under the production conditions, estimating of concrete mix rheological characteristics, volumetric aggregate concentration and impurity are very important to adjust the allotment of concrete floor joint spacing. Influence of the above-mentioned factors on joint spacing is depicted in Fig 9 [17]. Fig 9 shows the change of joint spacing, depending on thickness of floor and estimated factor of shrinkage.

Many methods are used to construct joints. One of the most commonly used methods for sidewalks, slabs, driveways and similar members is grooving the plastic concrete with a grooving or jointing tool. When the concrete dries out and contracts, the joint opens up further to accommodate that volume change. Installation of a dummy (induced) joint is effected after the concrete has been edged, and prior to float-finishing of the surface. Forming strips of plastic or metal may be embedded in the cast concrete and carefully removed after the concrete has hardened. This leaves a joint of predetermined width and depth.

A joint must satisfy two conditions: it should serve to relieve stresses that develop in the concrete and it should permit the concrete to move freely without decreasing the floor utility. To meet these requirements the joint must be constructed in such a way that it does not fill with debris and cause spalling; it should maintain a flat, even surface from one section to the next; it must not fail to transfer loads across from one side to another.

4. Multiple criteria evaluation of simple monolithic concrete floor

In earlier research [18] the most rational solution of installation of monolithic concrete floor was established. This decision means an installation of simple concrete floor giving concrete mix by pump. Therefore the subsequent analysis was accomplished on the basis of this decision. Alternative variants of concrete floor were made, choosing different load (25-150 kN), concrete class (C20/25, C25/30, C30/37, C35/45, C40/50) and three constructional types of floor: not reinforced, reinforced by steel mesh and steel fibre.

At first, the analysis of direct expenditures was accomplished for establishing an influence of structural layer on total direct expenditures of concrete floor installation. The direct expenditures were calculated by [19–21].

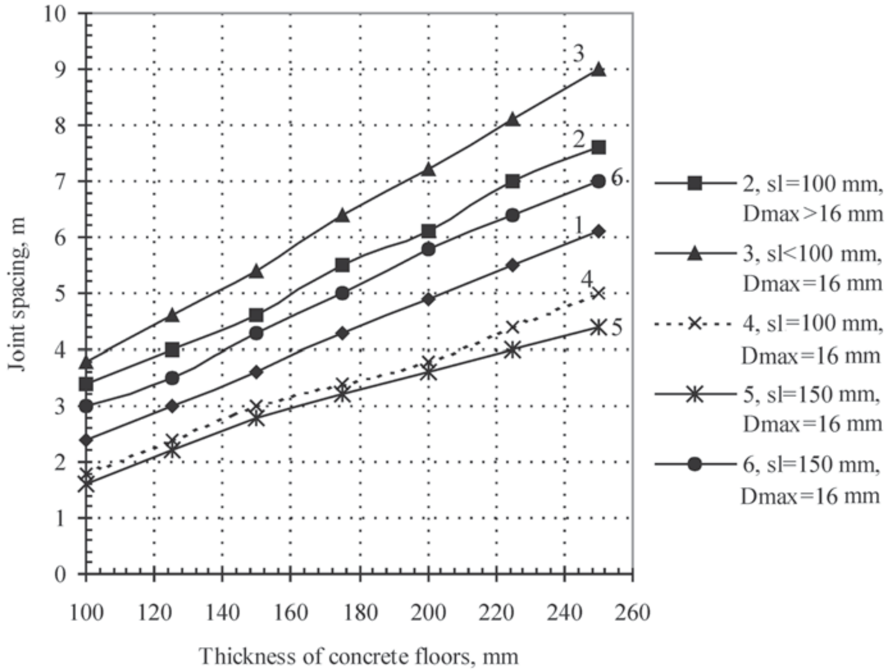

Fig 9. Scheme of joint spacing dependence on thickness of concrete floor, concrete mix slump and aggregate used: 1 – concrete mix slump sl = 100 mm, clean crushed granite or gravel, $D_{max} \leq 16$ mm; 2 – concrete mix slump sl = 100 mm, clean crushed granite or gravel, $D_{max} > 16$ mm; 3 – concrete mix slump sl<100 mm, clean crushed granite or gravel, $D_{max} \leq 16$ mm; 4 – concrete mix slump sl≈100 mm, unwashed crushed gravel, $D_{max} \leq 16$ mm; 5 – concrete mix slump sl = 150 mm, unwashed crushed gravel, $D_{max} \leq 16$ mm; 6 – concrete mix slump sl = 150 mm, crushed dolomite, $D_{max} \leq 16$ mm

When starting data (compressive strength of concrete, subgrade modulus, wheel spacing and the factor of safety) were represented, the thickness of concrete floor was estimated by Portland Cement Association method.

Thickness of floor, joint spacing and steel amount of structural decisions were established by Eq 1 and Figs 2–5, Table 4.

The analysis demonstrates that installation of subgrade amounts to 11–19 % of total direct expenditures, installation of concrete slab to 50–75 %, reinforcement to 9–21 %, steel fibre reinforcement to – 12–25 % and joint spacing to 3–24 % (Figs 10–12).

In order to estimate structural solution, installation technologies and the quality of concrete floor we have applied multiple complex proportional estimation method [7, 22–24].

This method assumes direct and proportional dependence of significance and utility degree of investigated versions upon a system of criteria adequately describing the alternatives and upon values of weights of the criteria.

System of criteria estimation consists in concrete floor thickness, direct expenditures of floor installation, joint spacing, reinforcing degree and thickness of subgrade (Table 5). The data were received by calculations.

The determination of significance, priority and utility degree of alternatives includes five stages:

1. Decision-making matrix is formed (Table 7);
2. The weighted normalised decision-making matrix is formed;
3. The sums of weighted normalised indexes describing are calculated;
4. The significance of comparative alternatives is determined on the basis of describing positive projects and negative projects characteristics. Relative weight Q_j of everyone project a_j is evaluated:

$$Q_j = S_{+j} + \frac{S_{-\min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-\min}}{S_{-j}}},\ j = \overline{1,n}, \qquad (4)$$

where n is the number of alternatives compared; S_{+j} – the sums of weighted normalised maximising indexes; S_{-j} – the sums of weighted normalised minimising indexes; j – alternative of a solution.

5. Project priorities are established. The value of Q_j is larger; the project efficiency is greater [7].

The alternative variants of multiple criteria evaluation are represented in Table 5.

In order to determine criteria weights, pair-wise comparison was used, thus variants compared in pairs. For performance evaluation a scale is chosen (0,2). If both criteria are equally significant, then will be equated 1; if one more significant for another – 2, then to another it is given 0. Results are presented in Table 6 [7].

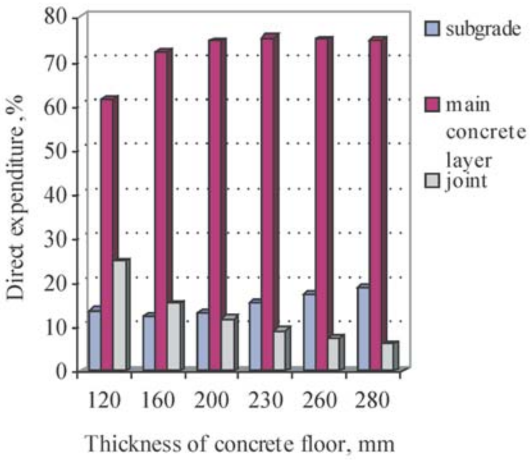

Fig 10. Direct expenditure of structural layers of plain concrete floor using concrete C30/37

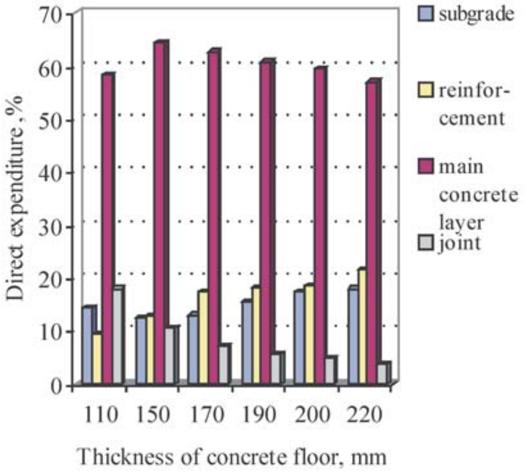

Fig 11. Direct expenditure of structural layers of reinforced floor using concrete C30/37

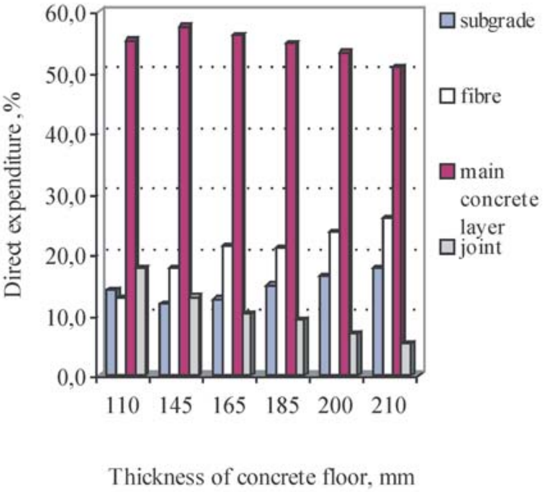

Fig 12. Direct expenditure of structural layers of steel fibre reinforced concrete floor using concrete C30/37

Table 5. Alternative solution variants of concrete floor

Code of variants	Description of concrete floor variants
NR1	plain concrete floor (axle load – 50kN)
NR2	plain concrete floor (75kN)
NR3	plain concrete floor (100kN)
R1	reinforced concrete floor (50kN)
R2	reinforced concrete floor (75kN)
R3	reinforced concrete floor (100kN)
F1	fibre reinforced concrete floor (50kN)
F2	fibre reinforced concrete floor (75kN)
F3	fibre reinforced concrete floor (100kN)

Dates, represented in Fig 13, demonstrate that fibre reinforced floor (axle load 50 kN) is the rational variant of installation of monolithic concrete floor. Labour expenditures are reduced due to steel fibre reinforced concrete, because reinforcing is a necessary; when installing monolithic concrete floor, concrete mix can be cast in layers and is more simple way to install floor when grades is needful.

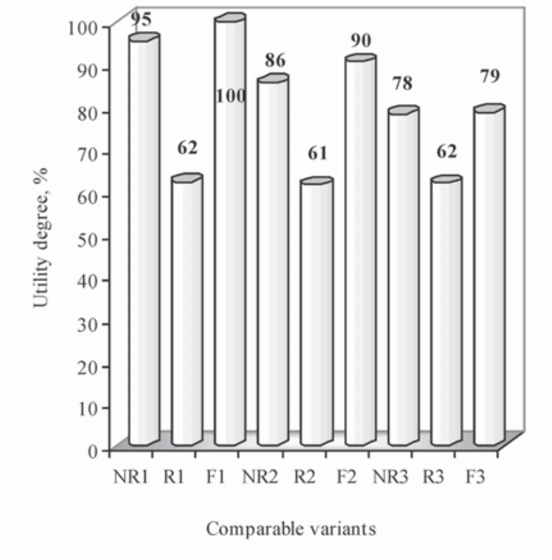

Fig 13. Utility degree of comparable variants

Table 6. Matrix of pair-wise comparison

i criterion	*j* criterion					
	1	2	…	*j*	…	n
1	–	x_{12}	…	x_{1j}	…	x_{1n}
2	x_{21}	–	…	x_{2j}	…	x_{2n}
…	…	…	…	…	…	…
i	x_{i1}		…	x_{ij}	…	x_{in}
...	…	…	…	…	…	…
n	x_{n1}	x_{n2}	…	x_{nj}	…	–

5. Conclusions

1. The principal measures of effective and qualitative monolithic concrete floor design and installation are presented.
2. The dependence of thickness of monolithic concrete floor upon the magnitude of loading, modulus of subgrade, reinforcement type and concrete class are determined.
3. The influence of steel fibre on monolithic concrete floor fatigue is analysed. The research indicates that steel fibre ratio l/d slightly influences the strain ratio and in practice one kind of fibre can be replaced another one.
4. Theoretically determined floor joint spacing in practical decisions needs to be corrected through evaluating concrete mix rheological characteristics, aggregate type, its volumetric concentration and impurity.
5. In order to evaluate monolithic concrete floor equipment technologies effectively, it is necessary to use advanced structural decisions, proper material and real expenditures.
6. According to the complex proportional estimation method of multiple criteria, evaluation is accomplished rational decision of installation monolithic concrete floor.

References

1. Žiogas, V.; Juočiūnas, S.; Medelienė, V. The problems and strategy of design and installation the high technical requirements of monolithic concrete floors. In: Progressive building (Pažangioji statyba). Proceedings of conference held in Kaunas, Lithuania 22–23th April 2004. Kaunas: Technologija, 2004, p. 206–211.

Table 7. Initial data for multiple criteria evaluation of monolithic concrete floor

Criteria	Significance of criteria	Optimality of criterion	Comparable variants								
			NR1	R1	F1	NR2	R2	F2	NR3	R3	F3
Direct expenditures, Lt/m^2	0,3	min	93	94	96	105	108	110	117	119	121
Thickness of floor, mm	0,15	min	165	150	145	200	175	165	230	190	185
Joint spacing, m	0,25	min	6	9	7	7	12	8	8	15	8
Reinforcing degree, %	0,2	min	0	0,08	0	0	0,1	0	0	0,13	0
Thickness of subgrade, mm	0,1	max	120	120	120	150	150	150	200	200	200

2. Bischoff, P. H.; Valsangkar, A. J.; Irving J. Use of fibers and welded-wire reinforcement in construction of slabs on ground. *Practice periodical on structural design and construction*, Vol 8, No 1, Febr 1 2003, p. 41–46.
3. ACI 360R-92. Design of slabs on grade. Construction practices and inspection, pavements manual of concrete practice. Part 2. Farmington Hills: American Concrete Institute, 2001. 800 p.
4. BS 8203. Code of practice for installation of sheet and tile floor. London, British Standards Institution, 1987. 28 p.
5. Handbook for concrete floor, Sweden, 1996. 292 p.
6. Juočiūnas, S.; Žiogas, V. Design methods for estimation of the thickness of monolithic concrete floor. In: Concrete and reinforced concrete (Betonas ir gelžbetonis). Proceedings of conference held in Kaunas, Lithuania 20–23th April 2002. Kaunas: Technologija, 2002, p. 111–115 (in Lithuanian).
7. Zavadskas, E. K.; Kaklauskas, A.; Banaitienė, N. Multiple criteria analysis of a building's life cycle (Pastato gyvavimo proceso daugiakriterinė analizė). Vilnius: Technika, 2001. 380 p. (in Lithuanian).
8. Migilinskas, D. The influence of normalization methods selection in construction including game theory adaptation. *Technological and economic development of economy* (Ūkio technologinis ir ekonominis vystymas), Vol IX, No 2, Vilnius: Technika, 2003, p. 73–79 (in Lithuanian).
9. TF 700R-03. Design of slab on ground foundation. Hartford: Wire reinforcement institute, 1981. 36 p.
10. Industrial concrete floor (Betonboden im Industrie-bau). Verlag Bautechnik, 1998. 180 p. (in German).
11. TM 5-809-1/AFM 88-3. Concrete floor slabs on grade subjected to heavy loads. Washington: Headquarters departments of the the Army and the Air force, 1987. 40 p.
12. TF 705-R-01. Formulas for success innovative ways to reinforce slabs on ground. Findlay: Wire reinforcement institute, 2002. 8 p.
13. Steel fiber reinforced concrete. Sunshine: Smorgon ARC, 1998. 71 p.
14. Falkner, H.; Teutsch, M.; Klinkert, H. Flexural strength of steel fibre reinforced concrete (Leistungsklassen von Stahlfaserbeton). Belgium: Braunschweig, 1999. 46 p. (in German).
15. Wei, S.; Jianming, G.; Yun, Y. Study of the fatigue performance and damage mechanism of steel fiber reinforced concrete. *ACI Materials Journal*, Vol 93, No 3, American Concrete Institute, 1996, p. 206–212.
16. ACI 224.3R-95. Joints in concrete construction. Use of concrete in buildings design, specifications and related topics. Part 3, Farmington Hills: American Concrete Institute, 2001. 800 p.
17. Žiogas, V. Rational use of coarse aggregates and employment progressive technology for arranging the monolithic concrete floor. In: Modern building materials, structures and techniques (Naujos statybinės medžiagos, konstrukcijos ir technologijos). Proceedings of the international conference held in Vilnius, Lithuania 21–24th May 1997. Vilnius: Technika, 1997, p. 106–111 (in Lithuanian).
18. Žiogas, V.; Juočiūnas, S. Analysis of technologies of installation monolithic concrete floor. *Journal of Civil Engineering and Management*, Vol IX, Suppl 1. Vilnius: Technika, 2003, p. 32–39 (in Lithuanian).
19. Standards of expenditure of labour, materials and machinery in buildings. Part 2 (Darbo, medžiagų ir mechanizmų sąnaudų statyboje normatyvai). LRSUM. Vilnius: Sistela, 1998. 282 p. (in Lithuanian).
20. Standards of expenditure of labour, materials and machinery in buildings. Suppl 6 (Darbo, medžiagų ir mechanizmų sąnaudų statyboje normatyvai). LRAM. Vilnius: Sistela, 1999. 96 p. (in Lithuanian).
21. Countable prices of building resources (Statybos resursų skaičiuojamosios kainos). LRAM. Vilnius: Sistela, 2004. 104 p. (in Lithuanian).
22. Vilutienė, T.; Zavadskas, E. K. The application of multicriteria analysis to decision support for the facility management of a residential district. *Journal of Civil Engineering and Management*, Vol 9, No 4. Vilnius: Technika, 2003, p. 241–252.
23. Trinkūnas, V. Internet-based decision support system of construction products (Statybinių medžiagų ir gaminių pirkimų sprendimų paramos internetinė sistema). Synopsis of a thesis. Vilnius: Technika, 2003. 42 p. (in Lithuanian).
24. Lepkova, N. Facilities management multiple criteria analysis of public buildings (Visuomeninės paskirties pastatų ūkio valdymo daugiakriterinė analizė). Synopsis of a thesis. Vilnius: Technika, 2003. 41 p. (in Lithuanian).

MONOLITINIŲ BETONINIŲ GRINDŲ PROJEKTAVIMAS IR ĮRENGIMO TECHNOLOGIJŲ YPATUMAI

V. Žiogas, S. Juočiūnas

Santrauka

Analizuojamos monolitinių betoninių grindų projektavimo, įrengimo technologijų ir vykdytojų parinkimo problemos bei šių veiksnių įtaka grindų kokybei ir efektyvumui. Nagrinėjama metalinio pluošto kiekio, jo techninių charakteristikų įtaka betono stipriui lenkiant, įvertinant betono stiprio klasę ir monolitinių betoninių grindų nuovargį. Įvairiems monolitinių betoninių grindų konstrukciniams sprendimams pateikiami siūlių išdėstymo sprendimai, atsižvelgiant į grindų storį, armavimo tipą ir naudoto betono mišinio charakteristikas. Efektyviai grindų įrengimo technologijai nustatyti atlikta monolitinių betoninių grindų pagrindinių konstrukcinių elementų įrengimo išlaidų lyginamoji analizė. Remiantis konstrukcinių sprendimų, technologijų ekonominio įvertinimo realiais duomenimis ir pritaikius kompleksinio proporcingumo metodą, atliktas monolitinių betoninių grindų įrengimo technologijų daugiakriterinis įvertinimas.

Raktažodžiai: monolitinės betoninės grindys, projektavimas, grindų storis, siūlių išdėstymas, armavimas, įrengimas, tiesioginės išlaidos, daugiakriterinis įvertinimas.

Vigantas 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.

Svajūnas JUOČIŪNAS. Dept of Civil Engineering Technologies. MSc (2000, civil engineer) at Kaunas University of Technology. Research interests: technologies of monolithic concrete floors, monolithic building technologies.