

Arrangement of construction joints in cast-in-place slabs

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Abstract Within latest decades cast-in-place construction of residential houses has been actively developed. Works on erection of cast-in-place frame of the building are normally performed by phases, which results in a necessity to arrange construction joints of concreting. In accordance with regulatory documents, it is allowed to arrange construction joints in any place of the slab, in parallel with its less side. As well, it is necessary to observe the technology for joint arrangement. As practice shows, observing only technology of construction joint arrangement is insufficient to provide for strength properties of cast-in-place reinforced-concrete slabs. This article provides an analysis of actual geodetic pre-construction surveys, design and theoretically-calculated solutions; case study is a multi-storied building under construction. On which basis, excessive slab deflections in the places of construction joints, were detected. It is established, that the main reason for deflection occurrence is early removal of slab formwork and installation of supports for temporary supporting. On the basis of obtained findings authors make conclusions regarding compulsory observance of the technology for construction joint arrangement, regarding a necessity to remove formwork according to common standards 70.13330.2012; as well, it is recommended to leave formwork under construction joints until concrete gains 100% of ruggedness.

1. Introduction

Within latest decades cast-in-place construction of residential houses has been actively developed. One of advantages of such houses is the possibility for free layout. As well, those houses attract by their reliability and lifetime.

Works on erection of cast-in-place frame of the building are normally performed by phases. In case if the building has considerable lateral extent, works on concreting are performed by “pours”. In connection therewith, a necessity to arrange construction joints in structures occurs. Concrete joints are horizontal and vertical. Horizontal joints are those between slabs and vertical structures (columns, walls) [1]. Arrangement of such joints is provided in design documents and they are obligatory for performance at the construction site. Vertical joints are those in cast-in-place walls or in slabs, they are not provided by the design company; however, where necessary, such joints may be performed by contractors subject to

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requirements of the norms which allow arrangement of construction joints, for example, in slabs in any place in parallel to the short side to common standards 70.13330.2012 (revised edition architectural and technical requirements 3.03.01-87) with obligatory agreeing upon of joint location with designers “in working order” (fig. 1).

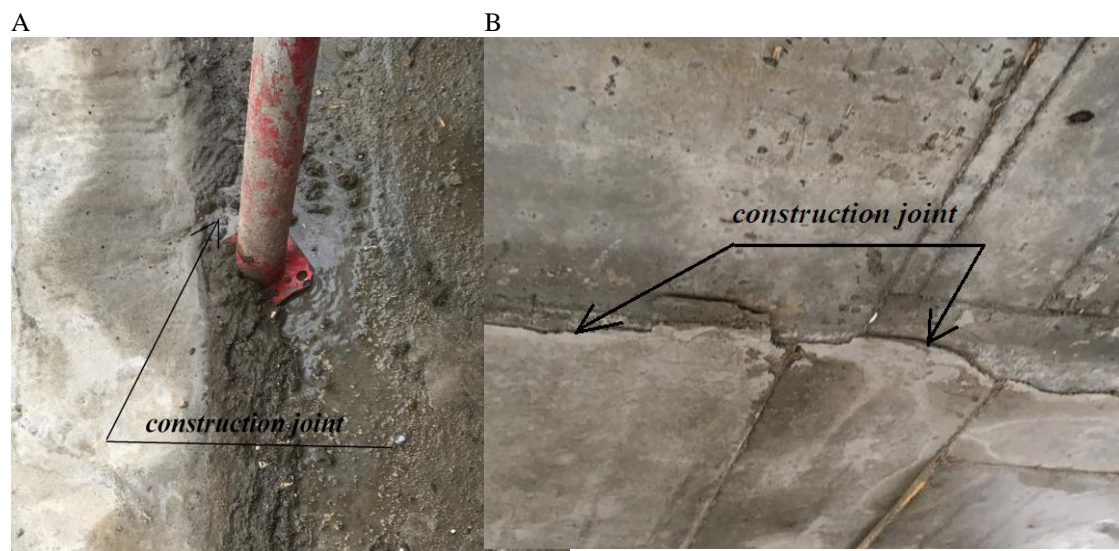


Fig. 1. A. Construction joint, top of slab, B. Construction joint, bottom of slab

However, low-quality performance or incorrect positioning of such joints may adversely affect carrying capacity of building structures in general. Therefore, currently, a necessity for more detailed studying of this issue occurs. Today, this problem gains more and more actuality and is highlighted in works by various authors. In works [2-7], authors consider a technology for arrangement of concrete joints (fig. 2) according to which the joint must be cleaned of dirt and garbage, flushed with water and dried with air jet, as well they provide findings of laboratory experiments with reinforced-concrete beams and other samples. In their works, the authors come to a conclusion that at designing, detailed studying of structures is required irrespective of building class, which, subject to various reasons (including process reasons) are implied to be performed with arrangement of construction joints. This is substantiated by the fact that poor-quality arrangement of joints adversely affects ruggedness of such construction elements and their deformation under load, though at designing a cast-in-place building is calculated as integral cast-in-place one, without joints.

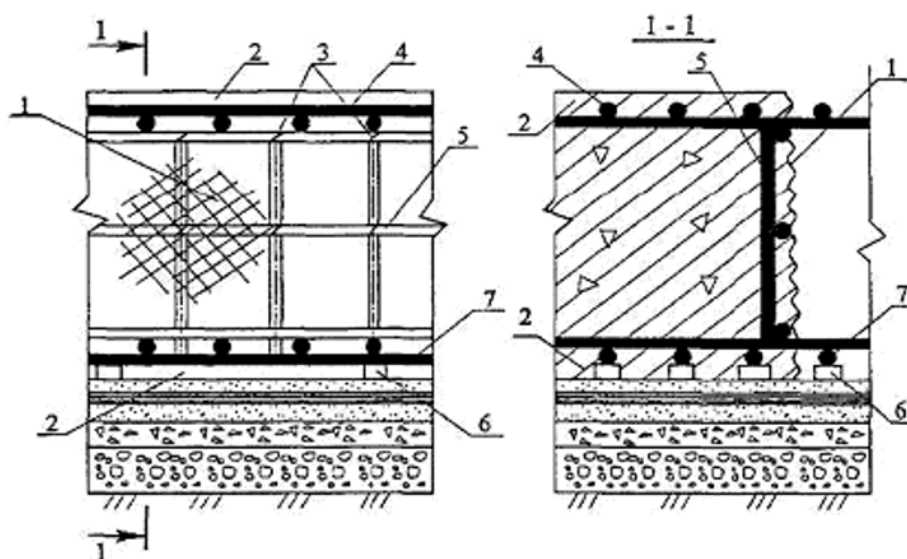


Fig. 2. Construction joint structure: 1 - metal grid; 2 - protective concrete layer;
 3 - spots of grid fastening with tying wire; 4 - top reinforcement;
 5 - flat supporting frame; 6 - plastic locks; 7 - bottom reinforcement

Works by other authors [8] describe arrangement of construction joints in foundation slabs. The article specifies that “perfect positioning of concrete joint must comply with the position of a zero transverse force of the structure, i.e. the joint is arranged where the transverse force is minimal, or even better it should be equal to zero. This is defined by estimate results, namely, by shearing-force diagram”. As well, the authors pay special attention to concreting technology at arrangement of construction joints. In closing, the authors make a conclusion that this matter is very poorly studied; and that today regulatory documents which regulate arrangement of construction joints, are not available.

Articles [1-8] are also united by the fact that they specifically stress that construction joints are a trouble spot which might adversely affect carrying capacity of the structure in general; and that in order to reduce adverse effect of concrete joints over structure’s carrying capacity, they must be performed with strict technology observance. Whereas, a number of authors [1,8] specify absence of an opportunity, at design phase, to foresee the actual locations where construction joints will be performed. Thus, correct observance of the technology allows to reduce the risk of emergency situations (occurrence of cracks and excessive deformations in joint arrangement spots). According to p.5.3.6 of common standard 70.13330.2012, concreting procedure should be developed with provision of concrete joint location, subject to erection technology for the building and the structure, as well as to its construction peculiarities; whereas, necessary ruggedness of concrete-surface contact within the concrete joint, as well as ruggedness of the structure subject to concrete joint availability, must be ensured. However, according to article authors, observance of only joint arrangement technology is insufficient to provide for ruggedness of the whole structure; therefore, it is necessary to consider issues of formwork dismantling [9-11] in construction joint locations.

2. Methods

Consider the matter of concrete joint arrangement, case study is a residential house under construction in Moscow city. The building is of L-shape, it consists of 6 sections comprising 16, 18 and 20 floors with underground parking (fig. 3). Foundations, walls, pillars and slabs of B25 class cast-in-place reinforced concrete.



Fig. 3. General view of the complex under construction

At this project, at the phase of concreting work planning, average amount of concrete per day which is necessary for structure arrangement, subject to economic considerations, was calculated: pay-off of column crane operation, as well as provision for optimal labour flow. Thus, per each crane it was calculated to pour in average 1,200 cubic metres of concrete per month, i.e. around 40 cubic metres per day (including 15 cub.m. were designated for vertical structures, and 25 cub.m. - for slabs, which, subject to slab thickness of 200 mm., constituted 125 sq.m.). On the basis of this figure, locations of possible cut-offs, subject to average pouring area, were forecasted. Prior to work commencement, this information was operatively provided to designers, so that they agree upon spots for concrete-joint arrangement or could provide suggestions as to their arrangement. Subject to calculations made, designers recommended to arrange joints in the area $1/4$ - $1/3$ from the value of slab span along the smaller side, which does not contradict requirements of common standard 70.13330.2012. However, in practice, visible deflections of slabs in construction joint areas, are observed. In order to determine compliance of those deflections with regulatory allowances, analysis of information obtained as a result of surveying measurements and theoretical calculations, was performed. Surveying measurements were performed on the project by Sokkia CX-105 tacheometer. Theoretical methods for calculating structure deflections were performed in STARK_ES of STARKON software package ("Eurosoft" LLC). STARKON software package is designated for static and dynamic computation of unspecified flat and spatial structures, as well for computation by ultimate states and for designing elements of construction structures (cross sections, beams, columns, slabs, foundations) as well as units thereof.

3. Results

As a result of geodetic measurements on six typical floors, post-construction surveys of slab deviations from the design position in the places of construction joint arrangement,

were obtained. Performed analysis of those surveys demonstrated availability of slab deflections [12-14] in the areas of joint arrangement. Areas of major deflections coincide in all the six floors, values of deflections range within 27 to 35 mm. Therefore, in the article, consider survey of 10th floor slab (fig. 4). Construction joints were performed according to common standard 70.13330.2012 in parallel with the smaller side of the slab, as well subject to approval with the designer organization, constituting 1/4 of span. Fig. 4 demonstrates that the maximal slab deflection amounted to 28 mm.

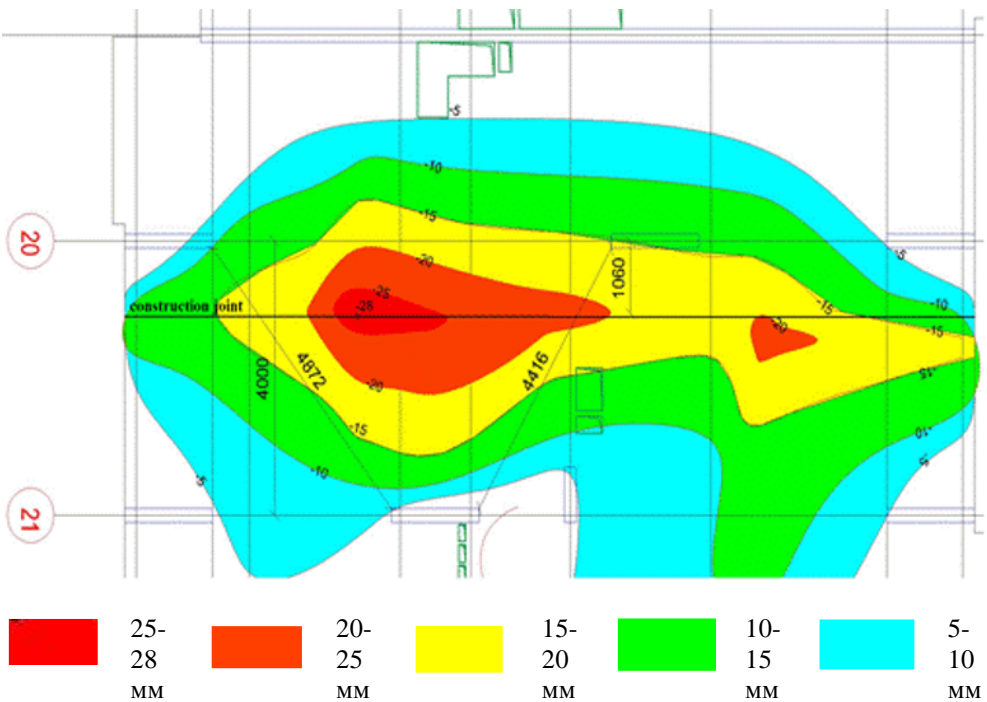


Fig. 4. Actual deflections of the slab (area near joint)

Computation of slab deflections was also performed with the use of STAR_ES 2015. The slab was computed as integral cast-in-place one. As well, all the loads were taken into account, as provided by common standard 20.13330.2010 (revised edition architectural and technical requirements 2.01.07-85 Loads and impacts). On the basis of performed computations of typical floor slabs, it is obvious that maximal estimated slab deformations (figure 5) constitute not more than 5.5 mm. Whereas, the moment diagram Mx (fig. 6) provides clear understanding as to positioning of areas with “zero” moments, in which areas designers suggest locating concrete joints.

According to Attachment D common standard 20.13330.2010 vertical limit deflection of the slab is limited by aesthetic-psychological requirements and constitutes for our span the value of 27 mm. Thus, actual deformations of the slab in the area of concrete joint arrangement being 28 mm., already exceed the limit value of deformation, which contradicts to requirements of regulations. However, one should not forget that the post-construction survey was performed in the period when construction and mounting works as to erection of the carrying frame of the building were not completed yet, while finish works are not commenced yet; and, therefore, not all the theoretically-calculated loads are applied. Subject to the above said, values of actual deformations, as measured by surveyors, may be for sure increased by 25-30%. Then, subject to real situation, forecasted values of actual de-

flections will considerably exceed limit ones and further perspectives of both construction completion and safe operation of the building without additional activities, become hard to perform.

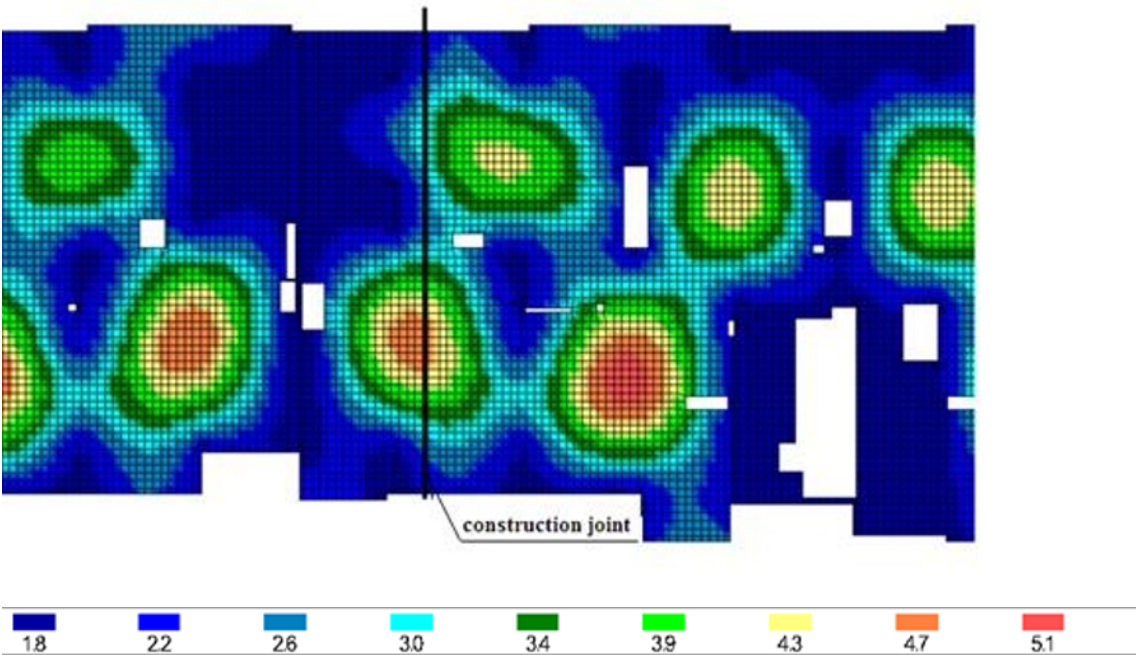


Fig. 5. Computed isofields of slab deformations (area near joint), mm

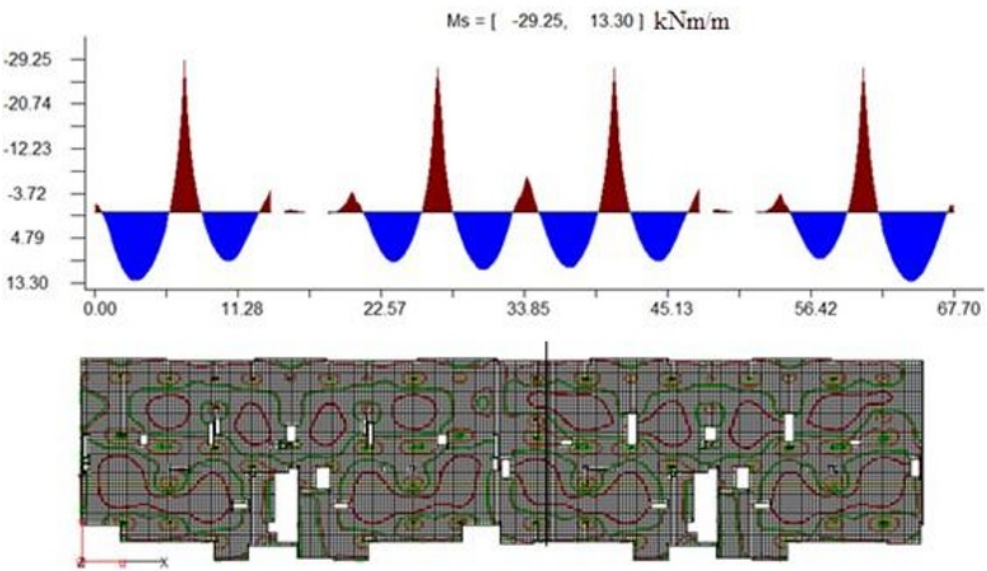


Fig. 6. Plot of Moments M_x along the slab

4. Discussion

After analysing the obtained results, one may specify one of reasons for development of excessive construction deflection in the area of concrete joint arrangement. This is related to additional deformations resulted from own weight of the cast-in-place reinforced-concrete slab, due to early partial removal of formwork (including in the areas of construction-joint arrangement), when concrete has not yet gained necessary ruggedness which complies with regulatory requirements (fig. 7, 8). One of the reasons for early removal of formwork may be Developer's saving of formwork at the construction site and reduction in construction period for the account of faster performance of concrete works



Fig. 7. Process of formwork removal



Fig. 8. Partial formwork removal. One team works ahead of schedule for 24 days.

One team works ahead of schedule for 24 days. Regulations (common standard 70.13330.2012) contain no definite instructions as to when it is necessary to remove formwork in the area of concrete-joint arrangement. They specify that slab formwork may be removed if concrete of unloaded structures gains 70% of design value, with spans of up to 6 m.; however, at partial removal of formwork, it can be removed even earlier. So far as, regulatory documents do not set out what is implied under “partial removal of formwork”, as a rule, instead of formwork, mobile pillars of “temporary support” are used (fig. 7, 8). Computation of the quantity and the pitch of supports is provided in the project method statement (further - PMS) and constitutes as a rule 1 support per 4 sq. m. In the case where it is about removal of formwork of “loaded structures”, including from above laying slabs, regulations (common standard 70.13330.2012) require to specify the value of the minimal ruggedness of concrete in the project method statement with compulsory agreeing upon of that

value with the designer organization. However, the following picture is observed in construction practice: a part of the slab is poured on one day, and already in a day or two the remaining part of the slab is additionally poured. Removal of formwork is commenced on the 2-3 day and temporary supports are installed; after that, in 5-6 days over the first area of the slab, the slab of the following floor is poured, and so on. Thus, the following situation occurs: the below lying slab is loaded by the following slab, while concrete ruggedness is only gaining 70% of the design carrying capacity. For our project, this is evidenced by opinions of the laboratory which performed laboratory tests on establishing the ruggedness of slab concrete by non-destructive methods [15,16]. Within the process of construction, a fact occurred: at the moment of pouring a part of the slab, the below lying slab lowered by 1 cm. Due to a number of reasons, it is quite difficult to establish the moment when just poured slab will get additional deformations. Numerical establishment of actual slab deformation values is performed after mounting of building frame, prior to commencement of performance of works of flooring arrangement, when the contractor requests (or performs using own resources) executive surveys according to actual position of slabs. Due to excessive deflections, a necessity occurs to arrange flooring of larger thickness, which exerts additional impact over the carrying capacity of the structure. Such impact is not counted in designing phase. Currently, more and more often, built housing complexes are sold without finish works, which entails that immediately the buyer faces the problem of “bent” slabs both of the flooring and ceiling. This information may reach the customer and the designer only when the buyer, prior to purchase of the apartment, has ordered so-called construction expert evaluation. The same may detect various defects [17-19] and structure damages (including those described above), which require instant removal by the seller. Removal of those defects requires additional financial costs [20]. But this is a subject matter of another article.

5. Conclusion

1. Where possible, arrangement of vertical construction joints in slabs should be avoided. Slabs should be poured from one expansion joint to the other.
2. If p. 1 is impossible to perform, it is necessary at the design phase to establish respective spots for concrete-joint location and, where necessary, to provide respective activities which reduce possible adverse effect upon carrying capacity of structures
3. Technology for construction-joint arrangement, as provided by common standard 70.13330.2012 must be strictly observed.
4. In order to prevent occurrence of excessive slab deflections, it is necessary to dismantle formwork according to requirements of common standard 70.13330.2012, after concrete of unloaded slab gains 70% of design ruggedness or, if it is planned to load the slab - minimal ruggedness should be specified in the project method statement, with compulsory agreeing upon of the specified value with the design organisation.
5. Author of this article recommends to leave formwork under construction joints until concrete gains 100% of the design ruggedness.

Only when the above specified activities are observed, one can speak about absence of adverse effect of concrete joints in cast-in-place structures upon carrying capacity of both separate structures and the whole building; as well, safe operation of the constructed building throughout its design service-life will become possible, which depends on building class and equals to at least 50 years for mass construction buildings under normal operating conditions state common standards 27751-2014.

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