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RESEARCH AND ANALYSIS OF THE FEASIBILITY OF THE CHOICE OF VOID FORMERS FOR MONOLITHIC REINFORCED CONCRETE SLABS

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The purpose of this review is The choice of materials for the manufacture of a non-removable void former is made on the basis of a comparison of the energy consumption for their production, optimization of the shape, manufacturing technology and use of a non-removable void former, and an analysis of calculations proving the effectiveness of this technology.

Void Formers are used to fill in empty areas beneath a ground concrete slab pour to reduce the volume of concrete required whilst maintaining the overall strength of the slab. They are also used to create void areas where conventional formed areas are not possible. They are not popular in Kazakhstan and just starting couple of experimental projects in country.

On the issue of the construction of such slabs with void formers, the latest scientific articles from the site scopus.com were reviewed.

The results of the review showed that these problems are still insufficiently developed and are very poorly covered, including in the normative literature. And the use of this technology in our climate and in domestic construction has not been studied anywhere.

In this regard, the best materials and forms of void formers and calculations for the construction of this technology were analyzed and selected.

Overall analysis. In order to reduce the amount of concrete and self-weight of flat slabs, plastic void formers are used in slabs. The most critical areas of flat slabs are slab–column junctions and the zones where huge concentrated loads act. This area is more prone to punching shear failure. The cross section of concrete in reinforced concrete slabs with plastic void formers is significantly smaller, and hence the punching shear capacity of such junctions is insufficient. This article discusses the results of an experimental and theoretical study that investigated the punching shear capacity of reinforced concrete biaxial voided slabs. In order to increase the punching shear capacity of flat slabs, shear reinforcement is provided between voids in the concrete ribs. Slabs with void-forming inserts placed in the entire slab area, voided slabs with solid cross shapes and voided slabs with solid heads were analyzed in this study. A method to calculate punching shear capacity based on EC2 methodology has been proposed. The results obtained for the punching shear capacity of the experimental slabs were verified with the EC2 methodology, and a method to calculate the length of the punching shear perimeter has been proposed [1].

The numerous advantages of solid slabs, including adequate rigidity, appropriate fire resistance, and sound insulation, have further extended the system's applications. The main disadvantage of this system is, however, its extreme weight, especially in long spans. Since concrete is not involved in bearing in the tensile zone, its removal can lower the weight without affecting the load bearing of the slab. In a number of systems, named biaxial voided slabs, ellipsoidal or spherical sacrificial plastic balls are used to create voids within the concrete. As this system has just been introduced, considerable uncertainties have been raised about one-way and two-way shear behaviors of the system. Accordingly, four full-scale specimens were built in order to investigate these behaviors. Two one-way and two two-way full-scale shear specimens with dimensions of 3500 × 1200 × 200 mm and 2300 × 2300 × 200 mm (length × width × height) were constructed, respectively. These specimens were used to compare the shear capacity, cracking distribution, and deflection in solid and biaxial voided specimens. Also, the effect of vertical rods of steel cages on the shear behavior was investigated. The results show the steel cages clearly contributed to shear bearing; and although the shear capacity of voided specimens was less than solid ones, the failure mode of all specimens was shear. Finally, a new method was proposed to predict the ratio of shear capacity of biaxial voided slabs to solid slabs. Hence, the proposed method can predict the ratio of biaxial voided capacity to solid slab capacity with an adequate precision [2].

Biaxial voided slab is an emerging slab system which reduces its self-weight up to 50% in comparison with the conventional reinforced concrete solid slab. The reduction in the concrete volume does not affect its flexural capacity significantly, however, it reduces both one-way and two-way (punching) shear capacity about 40%. Therefore, an effective way of predicting the punching shear capacity is investigated as the presence of voids alters the critical failure section. The applicability of conventional methods for solid slabs in the design standards, such as ACI 318 (2014), EN 1992-1-1 (2004) and IS 456 (2000) to predict the punching shear capacity of the voided slab is examined. In addition, eight full-scale specimens were tested with the sphere and cuboid shape of voids. Finally, experimental results of present study and test data collected from literature (33 specimens) were compared with predictions by the relevant code provisions. The estimation of punching shear capacity of biaxial voided slab by existing provisions for solid slabs in standards does not lead to satisfactory results. Hence, the presence of voids is considered by modifying the critical section depending on the void location. Further, only the effective concrete area is considered to predict the punching shear capacity. After the modifications, the predictions by all three building standards lead to satisfactory results [3].

Regarding the punching shear strength of voided slabs, several studies have been performed in which different shapes of the inserts were used. The results found that the punching shear strength of the voided slabs was remarkably lower than that of the conventional solid slabs because of a reduction in the critical concrete section owing to placing the voids near columns. Also, the shape of voids was found to have a considerable influence on the punching strength. On the other hand, the studies stated that the bubbled slabs could achieve the same punching strength of solid ones when a solid area (without inserts) was introduced around columns. Generally, there is no consensus on the dimensions and shape of the solid zone [4].

Concerning the flexure strength of two-way voided slabs, the results reported by Coreyshowed that the flexural strengths of slabs with voids, placed under the compression zone, were similar to that of control (solid) slab. The same conclusion was addressed by Chung et al. However, another investigatioindicated an 11.0% drop in the flexure strength of bubbled slabs. Also, the presence of voids led to decay in the flexural stiffness, nearly 20%, in comparison with an identical solid slab. The differences in the results were due to using various shapes of voids in these investigations. Nimnim and Zain Alabdeendemonstrated that the void shape significantly influenced the two-way flexural strength of voided slabs, and spherical voids gave better results than the cubical ones. Fatma and Chandrakar stated that the arrangement of balls inside slabs also affected their load-carrying capacity. The use of reactive powder concrete in manufacturing the voided slabs was found to remarkably improve the flexure strength, around 109%, compared to slabs made of normal concrete.

Four specimens were fabricated, representing a one-way slab with dimensions of 2000 mm × 500 mm × 120 mm. One slab (SOL) was solid without voids and assigned as a control slab. The others had a voided cross-sectional area by introducing 68 polystyrene balls inside them; the properties of these balls are listed in Table 1. To inspect the impact of the voids' size on the behavior of slabs, three diameters of balls were chosen: 60 mm, 70 mm, and 90 mm. Accordingly, the ratio of ball diameter to the slab depth (D/H) was 50%, 58.3%, and 75%, respectively. The bubbled specimens were identified according to the ball diameter as BA60, BA70, and BA90, respectively.

The voids were fixed in their positions, in addition to using binding wires, by bounding them with four steel bars from all sides at the top and bottom. Accordingly, the top and bottom steel meshes were identical for all slabs. These meshes consisted of 8Ø10 and 34 Ø10 deformed steel bars in the transverse and longitudinal directions, respectively. It is essential to state that the spacing between reinforcing bars varied, depending on the size and distribution of balls, as shown in figures below.

The location of the bottom mesh was constant for all specimens, 20 mm above the bottom face of the slab. In contrast, the position of the top mesh was different, according to the balls' size, ranging from 20 mm to 40 mm. The yield and ultimate strengths of reinforcing bars were 577 MPa and 670 MPa, respectively. The ratio of tensile reinforcement was 1.20%. This ratio is 29% lower than the maximum ratio required by ACI 318M-19 code to ensure the tension-controlled behavior for slabs (ductile behavior) [5].

The four slabs were fabricated using the self-compacting concrete. Several trial mixes were made, the target compressive strength was 45 MPa. In addition to this strength, the criteria for adopting the mix design was to fulfill the requirements. Accordingly, four tests were performed for evaluating the fresh properties of each trial mix, which were slump flow, T50, V-funnel, and L-box. In this mixture, all components were primarily mixed in a dry situation for five minutes. Then, nearly 70% of the required water was added to fluidize the mix for three minutes. Finally, the remaining water with a superplasticizer was added. The process of mixing then continued for an extra five minutes. Each slab was cast from one concrete batch; six standard cylinders with dimensions of 150 × 300 mm were taken from each batch for determining the compressive and splitting tensile strengths of concrete. All slabs and associated cylinders were kept wet at room temperature for 28 days after casting. Table 1 outlines the properties of test slabs.

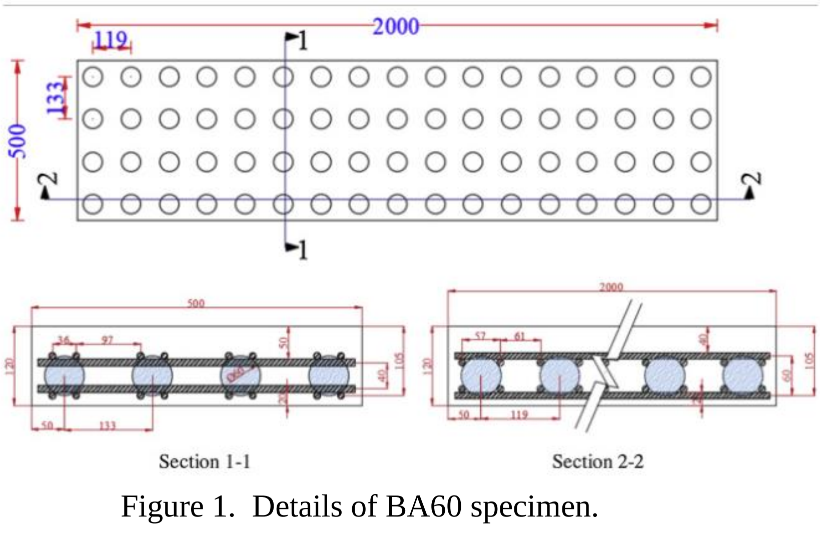

Figure 1. Details of BA60 specimen.

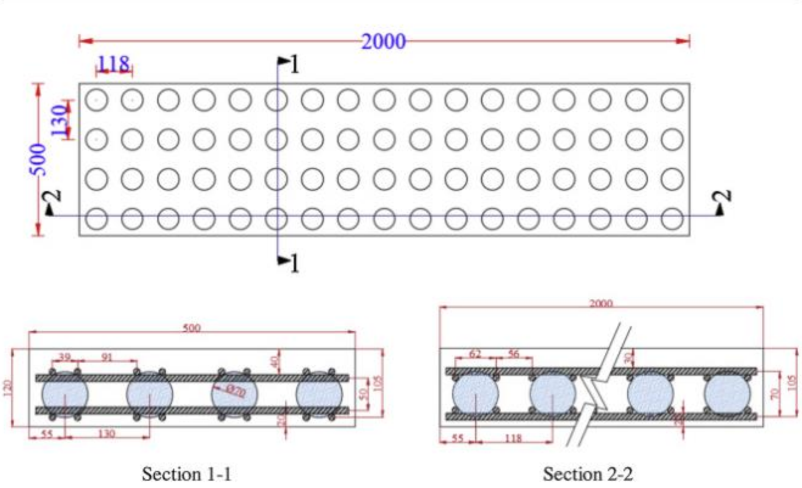

Figure 2. Details of BA70 specimen.

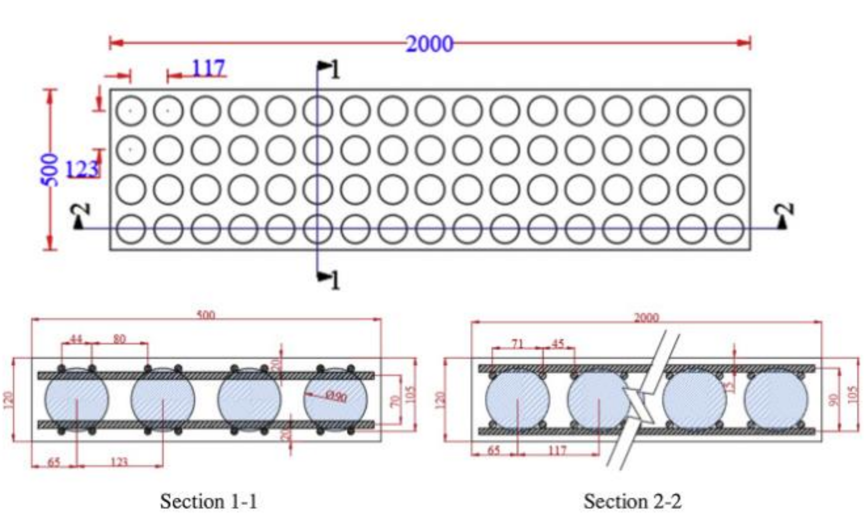

Figure 3. Details of BA90 specimen.

Table 1. Properties of test specimens

Specimen	Ball diameter (mm)	Cylindrical compressive strength, f_0 (MPa)	Splitting tensile strength, f_b (MPa)
SOL		47.3	4.5
BA60	60	48.8	4.9
BA70	70	47.6	4.6
BA90	90	45.5	4.2

All samples, except the BA90 slab, failed in the flexural mode; the BA90 collapsed owing to the brittle shear mode. This result means that introducing balls with a diameter equivalent to 75% of the slab depth led to changing the failure mode from flexural to shear, although the slabs were designed to fail in flexure.

The first crack was observed in the flexural span for all specimens, where the maximum moment occurred at loads of 23–48 kN. As expected, the bubbled specimens cracked at forces lower than that of the control slab because of the direct reduction in their moment of inertia due to eliminating the substantial volume of concrete by voids. The decline in the cracking load became more evident as the size of balls increased, as listed in table 2.

For specimens failed in flexure, more vertical cracks grew and spread over the flexural span with increasing the applied loads. Then with further load, these cracks augmented, enlarged, and propagated upward. The flexure-shear cracks also appeared in the shear span next to the loading points in the BA60 and BA70 specimens. Nevertheless, these cracks did not propagate and widen enough to cause failure. In these slabs, the flexural failure was distinguished by the arrival of flexural cracks nearly to the upper third of the specimen depth as well as the crushing of concrete on the top surface of specimens at the mid-span.

Conclusion. Though plastic voided slabs can be compared to conventional one-way slabs, plastic voided slabs are most efficient when designed similar to two-way slabs without support beams. For this reason, the parametric study compares interior bays of a flat plate system to interior bays of a plastic voided slab system. The primary goal of the study was to compare the relative weight of a plastic voided slab to the relative weight of a flat plate. Many parameters must be considered when designing a concrete slab. For a comprehensive comparison between two-way slabs and plastic voided slabs, a study must consider not only different bay sizes, but also span conditions and different weights and strengths of concrete. However, the purpose of this study was to provide a quick, illustrative comparison between flat plate slabs and plastic voided slabs. As a result, the two slab systems were compared by designing each for four different bay sizes

Although the primary financial benefit of using a plastic voided slab system rather than using a traditional two-way flat plate slab is the reduced amount of concrete, the amount of steel used for reinforcement is an item that must be considered. A design may reduce the amount of concrete, but if it greatly adds to the amount of reinforcement needed, the cost savings will not be as significant since material and labor costs for the steel will be greater. Therefore, the most important design consideration after slab thickness is the size and amount of reinforcement used in the section. Selections were made by choosing the smallest bar not requiring spacing that was judged to be too close. If a close spacing was required, a larger bar was examined. For a given section, a larger size of reinforcing bar requires the use of fewer bars and allows for wider spacing of the bars. Table 7-2 shows the type and amount of reinforcement that was used for each slab as well as the weight of the reinforcement. The percentage of reinforcement by weight for each plastic voided slab compared to the corresponding flat plate is also shown. Table 7-3 also shows the maximum moment and the moment capacity for each bay, as well as the percent utilization.

Reinforced concrete slabs are used in many modern buildings. As architects attempt to use more open layouts by utilizing larger column-to-column spans, concrete slabs can become thick and heavy when designing a traditional flat plate. As illustrated in the parametric study, plastic voided slab systems can be used to reduce the structure weight with minimal impact to the overall building design. The benefits of using plastic voided slabs rather than solid slabs are greater for larger spans. Smaller spans do not require substantially thick slabs, therefore only small voids can be utilized and minimal savings are achieved. Larger spans are capable of using larger voids that greatly reduce the overall weight of the slab while meeting load capacity requirements. Construction of plastic voided slabs requires more steps than solid slabs, but the construction process is not significantly more complicated. For bays of the same size, plastic voided slabs typically require less reinforcement. The only major change is placement of the plastic void formers. The void formers are placed above the bottom layer of reinforcement and are usually contained in a cage of very thin steel bars. The cage of void formers is typically constructed at the manufacturer's facility and shipped to the construction site, allowing for quick placement of the void formers and minimal changes to the construction schedule compared to solid slab systems. Architectural freedom can also be achieved by utilizing plastic voided slabs. Plastic voided slabs make it possible to achieve longer spans with the same amount of concrete in the slab, allowing for less columns and a more open interior space. Overall, plastic voided slab systems provide an excellent alternative to solid concrete slabs for many applications. Weight and cost savings as well as architectural flexibility can be achieved with plastic voided slabs.

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УДК 69.0

ИННОВАЦИОННЫЕ МЕТОДЫ ОПЕРАТИВНОГО ПЛАНИРОВАНИЯ В СТРОИТЕЛЬСТВЕ

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Введение. Строительная отрасль активно пытается решить проблемы низкой производительности, возникающие из-за неэффективного планирования строительства [1]. На планирование строительства существенно влияет множество неопределенных факторов, связанных с задачами строительства, окружающей средой, ресурсами, технологиями, персоналом и многим другим [2]. Одним из главных частей исследования является повышение эффективности строительного производства путем минимизации затрат времени и сопутствующих ресурсов на обеспечение своевременности и непрерывности строительных технологических процессов за счет совершенствования оперативного планирования на основе использования инновационных методов.

Основная часть. Строительную информацию из большинства проектов чаще всего трудно извлечь, она устаревшая и неполная из-за характера системы, используемой для ее создания или хранения [3]. Это может быть связано с традиционными или ручными инструментами, используемыми в строительной отрасли [4]. В то время как использование информационно - коммуникационных технологий (ИКТ) показало потенциал в решении проблемы сложности строительной деятельности и повышении производительности [5]**.**

Оперативное планирование в строительстве предполагает выявление наиболее эффективных и рациональных способов выполнения строительного проекта. Одним из традиционных методов оперативного планирования строительного производства является недельно - суточные планы-графики. Исходными данными служат оперативные месячные планы, календарные (сетевые) графики строительства, ППР и комплектовочные ведомости [6]. Необходимо отметить, что метод недельно-суточного планирования отличается высокой достоверностью информации, положенной в его основу и точностью расчетов, что позволяет составить строго обоснованное задание, наладить строгий контроль за его выполнением.

В последние годы появилось несколько инновационных методов, которые могут помочь строительным компаниям упростить процесс планирования и обеспечить успех проекта. Вот некоторые из инновационных методов оперативного планирования в строительстве: