UDC 624.01 DOI: 10.31650/2786-6696-2025-14-122-128

IMPROVEMENT OF COLD CONCRETE JOINTS USING WET GRINDING METHOD

[1]**Kyryliuk S.V.,** Ph.D., Assistant Professor,
kirilstani@ukr.net, ORCID: 0000-0002-8871-8302
[1]**Bichev I.K.,** Ph.D., Assistant Professor,
bichev@ukr.net, ORCID: 0000-0002-3000-2600
[1]**Bochevar K.I.**, Ph.D., Senior lecturer,
4871416k@gmail.com, ORCID: 0000-0003-4589-8080
[1]*Odesa State Academy of Civil Engineering and Architecture*
4, Didrikhson str., Odesa, 65029, Ukraine

Abstract. The article considers the process of cold joints formation that arise as a result of interruptions during the placement of concrete mix and can significantly affect the subsequent mechanical behavior of concrete and reinforced concrete structures. The characteristic defects that are formed both at the manufacturing stage and during the operation of structural elements, as well as their impact on durability and load-bearing capacity, are analyzed in detail. Special attention is paid to modern methods and materials used for the repair and restoration of damaged concrete elements, in particular, special repair mixtures, modified cements, chemical additives and approaches to base preparation. One of the key methods considered in the work is the technology of wet shotcrete, which allows for effective restoration of damaged areas and ensuring high-quality adhesion between old and new concrete. The features of regulating the technical properties of repair mixtures by using optimal compositions, selection of aggregates, modification of the mixture and control of hardening conditions are presented. The importance of proper surface preparation of existing concrete is emphasized, which largely determines the quality of the contact zone.

The study is aimed at determining the optimal parameters for applying repair materials by shotcrete. In laboratory conditions, partial application of a 1 cm thick layer of repair mixture was used using a compact test rig. A method for determining the tensile strength of fine-grained concrete during bending was developed using standardized forms modernized with special partitions. Prepared halves of beams with surface angles of 90°, 45° and 22.5° to the horizontal were used as elements of "old concrete". Such a design solution allowed to increase the contact area, minimize flow turbulence during spraying and assess the influence of the spatial position of the cold joint.

Within the framework of the study, a two-factor nine-point experimental design was formed, in which the angle of the cold joint plane (90°, 45°, 22.5°) and the speed of spraying the shotcrete-fiber concrete mixture (0 m/s, 35 m/s, 70 m/s) were varied. A set of experimental tests was carried out, the results of which are presented and analyzed in the work, which allowed us to establish the regularities of changes in the strength and nature of the fracture of the repaired samples.

Keywords: cold joint concreting, wet shotcrete method, repair work, partial shotcrete, experimental planning.

Introduction. The characteristics of the concrete structures depends largely on the integrity of the material throughout its volume. Sometimes, due to interruptions or delays in the concreting procedure, when the second batch of concrete is not poured immediately after the first one, cold joints occur [1-4]. In such situations, surface of weakness is created in the concrete element body, which can result in the structural problems in the final concrete structure [5].

Monolithic concreting is usually performed floor by floor, and delay in the concrete mix inevitably creates the potential for cold joints to form at column-slab and column-beam joints. Large foundation elements may require segmented concreting due to time constraints, creating parts prone to cold joints. Their location and dimensions should generally be determined by the type of structure in order to guarantee its functionality and aesthetic appearance [6].

Analysis of recent research and publications. The previous studies have mainly focused on the general effect of cold joints on concrete properties such as compressive strength, tensile strength and durability. However, the specific effect of cold joint arrangement on the bending behavior of concrete elements has not been thoroughly investigated. The ability of the system to withstand the maximum force depends on factors such as the location of the cold joint, the pouring interval and the relationship between the location of the cold joint and the direction of the applied forces [7].

The regulatory documents state that concrete mixtures are recommended to be arranged in structures that are concreted in horizontal layers of the same thickness without gaps with a consistent direction of laying in one direction in all layers. The surface of the construction joints arranged when laying the concrete mixture with interruptions should be perpendicular to the axis of the columns and beams, the surface of the slabs and walls that are being concreted. Re-concreting is allowed to be performed after the concrete reaches a strength of at least 1.5 MPa [8, 9].

In order to prevent the formation of cold joints and excessive settlement or overloading of the mould and its supporting structures, it is necessary to choose an appropriate speed for placing and compacting the concrete mix. During molding, a cold joint may form if the concrete mix hardens before the subsequent layer of concrete mix is placed and compacted. Special attention should be paid to the areas where previously placed concrete mix has not been compacted before placing the subsequent layer [10].

Before concreting, the location of the construction joints should be carefully considered and their position agreed. They should usually be located at right angles to the direction of the element. If special preparation of the joint surfaces is required, this should be indicated [8-10].

Partial shotcrete is applied to arrange cold joints using a shotcrete gun. With this method, a thin layer of shotcrete is applied for further concreting [11].

By analyzing the impact of cold joints and their control in different elements and at different angles, the study provides valuable information for construction, contractors and workers on the construction site in order to optimize construction protocols during large-scale concreting.

The purpose of the study presented in the paper is to determine the analytical dependences of the tensile strength index during bending of repair mixtures applied by wet shotcrete technology with a compact installation when arranging cold joints.

The objectives of the study are to analyze modern methods and materials applied for the repair of concrete and reinforced concrete elements of building structures and structures, including for the control of cold joints. To investigate the fracture of cold joints specimens placed at an angle.

Materials and study methods. When repairing with cement mortars and concrete, depending on specific conditions, special requirements are imposed on them: acceleration of the hardening rate, slowing down the setting process, the possibility of thinning the concrete mixture, no shrinkage or expansion, high density, chemical resistance and adhesion to "old" concrete. Regulation of the technical properties of concrete is achieved by applying special types of cement, additives and aggregates, special laying methods and hardening conditions, as well as appropriate preparation of the surface of old concrete [12, 13].

Partial application of shotcrete by wet method was carried out by a compact shotcrete installation (Fig. 1), which operates with compressed air from a mobile compressor station of appropriate capacity. The low-power operation of the compact installation can be effectively used for the installation and repair of thin-walled reinforced concrete elements of buildings. The bunker gun (hopper) is designed according to the principle of a compressor nozzle and has a bunker volume of 6 dm^3. With a coating thickness of 10 mm, in two layers, the gun's performance is about 10 m^2/h.

Compared to the dry method, the wet shotcrete method requires more work at the beginning (preparation and feeding the mixture into the pump) and at the end (cleaning the equipment). In addition, the wet shotcrete method has a limited time of use of the prepared mixture, and if the concrete mixture is not applied during this time, the mixture cannot be used.

The composition of the mixture for the wet shotcrete method contains: cement, inert materials, additives (superplasticizers), liquid, fibers (dispersed reinforcement). The same requirements are imposed on shotcrete-concrete mixtures in construction as on conventional concrete mixtures.

Fig. 1. Compact shotcrete installation:
1 – hopper; 2 – compressor; 3 – hose

It is much more difficult to achieve all of the above-mentioned requirements with wet shotcrete, especially on open construction sites. Previously, this was completely impractical, but today it is possible to approach the ideal composition of the mixture by means of special additives. A very important criterion for shotcrete mixtures is the number of small particles that make up the bulk of the composition, and the strength characteristics.

The concrete bases have high absorption and absorb most of the moisture from the repair mixture. To prevent the repair mixture from peeling off in the first year, a penetrating primer should be applied. For example, consider the use of Knauf Betokontakt as a preparation for high-quality finishing of concrete and foam concrete surfaces. The mortar does not penetrate deeply into the base and in most cases penetrates the surface at a level of 4-5 mm. However, the main advantage of this composition is that it creates high adhesion on porous surfaces. As soon as the liquid dries, a rough layer is formed, finishing materials adhere perfectly [14].

For an experiment to determine the tensile strength of fine-grained concrete during bending of the repair mixture. To check the adhesion of fine-grained shotcrete, a mold for beam samples 4×4×16 cm and finished half-samples in the form of old concrete with age of 1 day was used. This mold is most suitable for creating samples of fine-grained shotcrete for preliminary experiments. The ends of the finished halves were made at angles of 90° – according to the requirements of regulatory documents, 45° – average value, and 22.5° – similar to the natural angle of spreading of the concrete mixture, degrees with a change in the behavior of the air flow in the shotcrete technology and a change in the contact area (Fig. 2).

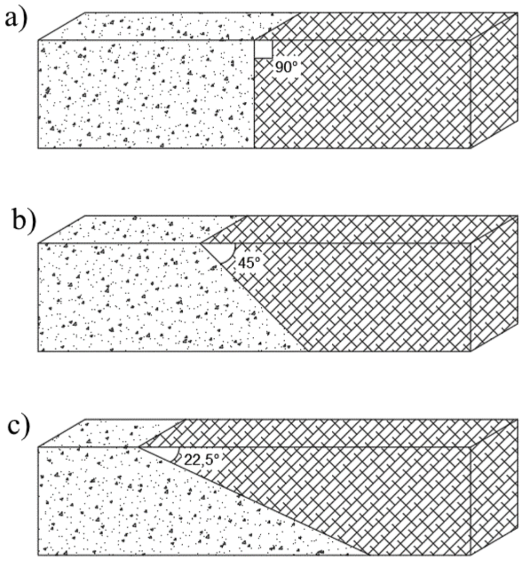

Fig. 2. Location of cold joints of beam samples:
a – 90°; b – 45°; c – 22.5°

Study results. The shortened experimental design with accepted factors was selected and ranges of variation of the parameters of the fine-grained shotcrete layer thickness are summarized in Table 1 [15, 16]. The study assumed changing the angles of the surface of the cold joints from 90° to 22.5° for the sanmples of the previous concreting layer, while the speed of the mixture supply varied from 0 to 70 m/s.

Table 1 – Experimental plan and parameter levels

No.	Normalzed values of factors		Natural values of factors	
	x_1	x_2	X_1	X_2
			Angle, °	Speed, m/s
1	-1	-1	90	0
2	-1	0	90	35
3	-1	1	90	70
4	0	-1	45	0
5	0	0	45	35
6	0	1	45	70
7	1	-1	22.5	0
8	1	0	22.5	35
9	1	1	22.5	70

The BauGut plasticizer was applied as a modifier. Due to this agent, it became possible to significantly increase the concrete mixture plasticity without the need to change the water-cement ratio, i.e. without increasing the water content, which facilitates the formation of a layer of fine-grained concrete during application.

To improve the physical characteristics of the material, basalt fiber was included in the composition of the fine-grained shotcrete mixture. To ensure the correct operation of the shotcrete installation with a bunker gun with a diameter of 9 mm, basalt fibers were crushed to a length of 3–4 mm.

The test samples were manufactured in standard molds intended for the formation of the beams made of fine-grained concrete measuring 40×40×160 mm (Fig. 3). The characteristics of the molds for the manufacture of such beams were as follows: type – beam mold (BM); number of samples – 3; width – 40 mm; length – 160 mm; height – 40 mm [15, 16].

Fig. 3. Partial shotcreting of the sample surfaces of the previous layer of concreting in a standard mold

The modified inserts were applied in order to prevent manufacturing defects in the lower corners caused by compressed air vortices during shotcreting. Following generally accepted practice for placing concrete, cement milk from the cold joint surface was removed in 24 hours, partially shotcreted and poured with the next layer of concrete.

In order to so simulate the conditions of monolithic structure concreting interruption, samples in the form of half-beams measuring 4×4×16 cm were applied as a base, one end of which was inclined at an angle of 90° to 22.5° relative to the horizontal. Additionally, this form was modified using insertable perforated partitions, which allowed the manufacture of shotcrete samples in a laboratory environment, taking into account the characteristics of the mobile equipment used for applying the mixture.

The samples were tested using MI-100 equipment, which is designed to determine the tensile strength of samples with a size of 40×40×160 mm i.e., which were manufactured in beam forms. The load is transmitted to the center of the beam, so the cold joint was located in the central part. The force acting on the beam is directed vertically, so the joint was located in the horizontal plane so that it contributes to the greatest loads. The adhesion of the sample cold joint at an angle of 45° withstands the forces that arise during destruction (Fig. 4). The plane of the beam section passes through the center and through the material of the previous and subsequent layers of concreting.

Fig. 4. Sample failure relative to the location of beam cold joints

Conclusion and further study prospects:

1. The preparation of the surface of previous concrete layer and the application of primers described in the paper contribute to improving adhesion when arranging cold joints.

2. The cold joints arranged according to the technology and placed at an angle withstand the load, and the destruction of the samples occurs in a different plane.

3. A compact installation for wet fine-grained shotcrete can be applied to arrange cold joints that arise during monolithic concreting.

4. A promising direction of study is partial shotcreting with a compact installation when arranging cold joints in heavy concrete.

References

[1] M. Maier, J. Lees, "Interlayer fracture behaviour of functionally layered concrete", *Eng. Fract. Mech.*, 271, 108672, 2022. https://doi.org/10.1016/j. engfracmech.2022.108672.

[2] M.A. Al-Osta, S. Ahmad, M.K. Al-Madani, H.R. Khalid, M. Al-Huri, A. Al-Fakih, "Performance of bond strength between ultra-high-performance concrete and concrete substrates (concrete screed and self-compacted concrete): an experimental study", *J. Build.*

Eng., 51, 1–17, 2022. https://doi.org/10.1016/j. jobe.2022.104291.

[3] G.B. Illangakoon, S. Asamoto, A. Nanayakkara, L. Nguyen Trong, "Concrete cold joint formation in hot weather conditions", *Construct. Build. Mater*., 209, 406–415, 2019. https://doi.org/10.1016/j.conbuildmat.2019.03.093.

[4] H.M.A. Mahzuz, M.M.H. Bhuiyan, N.J. Oshin, "Influence of delayed casting on compressive strength of concrete: an experimental study", *SN Appl. Sci*., 2, 1–7, 2020. https://doi.org/10.1007/s42452-020-2135-3.

[5] B.C. Zega, H. Prayuda, F. Monika, F. Saleh, D.E. Wibowo, "Effects of cold joint and its direction on the compressive and flexural strength of concrete", *Int. J. GEOMATE*, 20, 86–92, 2021. https://doi.org/10.21660/2021.82.J2086.

[6] J. Vanlalruata, C. Marthong, "Effect of cold joint on the flexural strength of RC beam", *J. Struct. Integr. Maint*., 6, 28–36, 2021. https://doi.org/10.1080/24705314.2020.1823556.

[7] Q. Qusay Ali, B. Erdil, T. Mohammed Jassam, "Critical cold joint angle in concrete", *Construct. Build. Mater*., 409, 2023. https://doi.org/10.1016/j. conbuildmat.2023.133881.

[8] DSTU-N B V.2.6-203:2015. Nastanova z vykonannia robit pry vyhotovlenni ta montazhi budivelnykh konstruktsii. DP «Derzhavnyi naukovo-doslidnyi instytut budivelnykh konstruktsii» (NDIBK). 2015.

[9] DSTU EN 13670:2023 (EN 13670:2009, IDT). Budivelni konstruktsii. Vyrobnytstvo betonnykh konstruktsii. Tekhnichnyi komitet standartyzatsii TK 303 «Budivelni konstruktsii», 2023.

[10] BS 8110-1:1997. Structural use of concrete design construction. British Standards Institution.1997.

[11] S.V. Kyryliuk, I.S. Chernov, A.V. Kyryliuk, "Adheziia pry vykorystanni chastkovoho torkretuvannia mobilnoiu ustanovkoiu", *Suchasne budivnytstvo ta arkhitektura*, no. 8, pp. 120-127, 2024. http://doi.org/10.31650/2786-6696-2024-8-120-127.

[12] Ye.M. Babych, V.V. Karavan, V.Ye. Babich, *Diahnostyka, pasportyzatsiia ta vidnovlennia budivel i inzhenernykh sporud* : pidruchnyk. Rivne. Volynski oberehy, 2018.

[13] A.G. Gungor, E. Sengun, Y. Yilmaz, I.O. Yaman, "Enhancing bonding performance in two-layer roller-compacted concrete pavements: Bridging laboratory insights with field performance", *Construction and Building Materials*, 418, 2024. https://doi.org/10.1016/j.conbuildmat.2024.135469.

[14] Knauf Betokontakt. [Online]. Available: https://knauf.kiev.ua/gruntovka/knauf-betokontakt-20-kg. Accessed on: May 10, 2025.

[15] DSTU EN 196-1:2019. Metody vyprobuvannia tsementu. Chastyna 1. Vyznachennia mitsnosti (EN 196-1:2016, IDT), 2019. (Natsionalnyi standart Ukrainy).

[16] DSTU B EN 12504-1:2013. Vyprobuvannia betonu v konstruktsiiakh. Chastyna 1. Zrazky kerni. Vidbir, perevirka i vyprobuvannia na stysnennia (EN 12504-1:2009, IDT), 01.01.2014. (Natsionalnyi standart Ukrainy).

УЛАШТУВАННЯ ХОЛОДНИХ ШВІВ БЕТОНУ МЕТОДОМ МОКРОГО ТОРКРЕТУВАННЯ

[1]**Кирилюк С.В.,** к.т.н., доцент,
kirilstani@ukr.net, ORCID: 0000-0002-8871-8302
[1]**Бічев І.К.,** к.т.н., доцент,
bichev@ukr.net, ORCID: 0000-0002-3000-2600
[1]**Бочевар К.І.**, док.філ., ст. викладач,
4871416k@gmail.com, ORCID: 0000-0003-4589-8080
[1]*Одеська державна академія будівництва та архітектури*
вул. Дідріхсона, 4, м. Одеса, 65029, Україна

Анотація. У статті розглянуто процес утворення холодних швів, що виникають унаслідок перерв під час укладання бетонної суміші та здатні суттєво впливати на подальшу механічну поведінку бетонних і залізобетонних конструкцій. Детально проаналізовано характерні дефекти, які формуються як на стадії виготовлення, так і під час експлуатації елементів конструкцій, а також їхній вплив на довговічність та несучу здатність. Окрему увагу приділено сучасним методам та матеріалам, що застосовуються для ремонту й відновлення пошкоджених бетонних елементів, зокрема спеціальним ремонтним сумішам, модифікованим цементам, хімічним добавкам та підходам до підготовки основи.

Одним з ключових методів, розглянутих у роботі, є технологія мокрого способу торкретування, яка дозволяє ефективно відновлювати пошкоджені зони та забезпечувати якісне зчеплення між старим і новим бетоном. Наведено особливості регулювання технічних властивостей ремонтних сумішей шляхом використання оптимальних складів, підбору заповнювачів, модифікування суміші та контролю умов твердіння. Підкреслено важливість належної підготовки поверхні існуючого бетону, що значною мірою визначає якість контактної зони.

Дослідження спрямоване на визначення оптимальних параметрів нанесення ремонтних матеріалів методом торкретування. У лабораторних умовах використовувалося часткове нанесення шару ремонтної суміші товщиною 1 см за допомогою компактної випробувальної установки. Розроблено методику визначення міцності на розтяг при вигині дрібнозернистого бетону із застосуванням стандартизованих форм, модернізованих спеціальними перегородками. Як елементи «старого бетону» використовувались підготовлені половинки балочок із кутами поверхні 90°, 45° та 22,5° до горизонталі. Таке конструктивне рішення дозволило збільшити площу контакту, мінімізувати турбулентність потоку при набризку та оцінити вплив просторового положення холодного шва.

У межах дослідження сформовано двофакторний дев’ятиточковий план експерименту, у якому варіювалися кут розташування площини холодного шва (90°, 45°, 22,5°) та швидкість набризку торкретфібробетонної суміші (0 м/с, 35 м/с, 70 м/с). Проведено комплекс експериментальних випробувань, результати яких наведені та проаналізовані в роботі, що дозволило встановити закономірності зміни міцності та характеру руйнування ремонтованих зразків.

Ключові слова: холодні шви бетонування, мокрий спосіб торкретування, ремонтні роботи, часткове торкретування, планування експерименту.

Стаття надійшла до редакції 24.10.2025
Стаття прийнята до друку 15.11.2025
Дата публікації статті 25.12.2025