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RESEARCH ON THE INFLUENCE OF MINERAL OILS ON THE STRENGTH AND AVERAGE DENSITY OF HEAVY CONCRETE

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Abstract. The article investigates the effect of mineral oils on the strength and volumetric weight of heavy concrete. Heavy concrete is the main material in construction, used to create structures with increased requirements for strength and stability, however, the effect of chemical agents, such as mineral oils, on its properties remains insufficiently studied. The study of this aspect is important for improving the durability and safety of concrete structures, in particular those exposed to oils in industrial processes or accidents. The aim of the study was to study how different types of mineral oils (transformer oil T-1500, engine oil 10W-40, IGP-30, both new and used) affect the physical and mechanical characteristics of heavy concrete, in particular its strength and volumetric weight. The experiments were carried out on concrete samples measuring 100×100×100 mm, made of Portland cement, under standard storage conditions. Oils were applied by two methods: immersion of samples in oil and application with a brush.

The results of the studies showed that the most significant effect on the strength and volumetric weight of concrete was the method of immersion of samples in new transformer oil T-1500, where after 30 days a significant increase in weight by 1.18% and compressive strength by 13.06% was observed. The use of waste oils and the method of applying oil with a brush led to a decrease in the strength of concrete, in particular, when using waste motor oil 10W-40, the strength decreased by 63.74% on day 30. At the same time, application of oil with a brush caused mainly superficial changes, without significant improvements or even a decrease in the strength of concrete. The results confirmed that the type of oil, its condition and the method of application have a significant effect on the mechanical properties of concrete. The study indicates the importance of choosing methods for protecting concrete structures from the negative effects of chemical agents and opens up prospects for further research in this area, in particular the development of technologies that reduce the impact of mineral oils on the durability and strength of concrete.

Keywords: heavy concrete, mineral oils, concrete strength, concrete average density, mechanical properties of concrete.

Introduction. Heavy concrete is one of the main materials used in construction, and it is widely used to create structures with increased requirements for strength and stability [1]. Despite its widespread use, questions remain about its durability and how its properties change under the influence of various external factors. One such factor is the influence of mineral oils, which are used in various industrial processes and can be present in the event of accidents or spills. Nevertheless, the mechanism by which mineral oils influence the physical and mechanical characteristics of concrete remains insufficiently studied.

Researching this issue is relevant because it provides a deeper understanding of how chemicals, particularly mineral oils, can alter concrete's basic properties, such as strength and density. These changes can significantly impact the performance of concrete structures, particularly their durability and safety. Since mineral oils have different chemical compositions and can be new or used, it is important to study how different types of oils affect concrete under various application methods. This research will contribute to a better understanding of the processes occurring in concrete under the influence of chemical agents and may form the basis for developing new recommendations for protecting concrete structures from aggressive influences. This is particularly relevant in industries where concrete is exposed to various chemicals.

Analysis of recent research sources and publications. The effect of mineral oils on the strength and average density of heavy concrete is an important topic in construction and materials science because using oils and petroleum products at various stages of construction can significantly impact concrete structure characteristics. Mineral oils, in particular, can alter concrete's physical and chemical properties, potentially decreasing its strength and durability.

Research into the effects of oils on concrete began several decades ago when serious defects caused by oiling concrete structures were discovered. Scientists such as K. Zelko, A. Bartosh, O. Volyansky, D. Plagin, T. Kostyuk, and V. Vinnichenko have devoted considerable attention to studying this phenomenon, focusing on the various ways oils impact the strength and durability of concrete structures. Notable foreign studies include the work of S. Stian, D. Weiss, R. Goshek, and W. Gray, which also confirm the importance of studying this issue.

One of the most notable studies is the research on how concrete strength decreases when it comes into contact with oil. One such study is by S. Chepurna, who found that oil – soaked concrete stops hardening and loses strength over time. Similar results were obtained in the study by Salau M. [14], who found a 12% decrease in the compressive strength of cement – sand mortar after two months of storage in lubricating oil.

Klymenko E. [4] found that storing concrete samples in mineral oil can lead to a 50% reduction in strength and that Portland cement concretes are more vulnerable to the effects of oils. Other researchers, such as Grynova, Shtukhets, Zelko, and Bartos, claim that oils decrease the axial tensile strength of concrete, particularly lower - grade concrete.

Studies on the effects of mineral oils on the physical and mechanical properties of concrete show that concrete with lower strength experiences a more pronounced decrease in strength. Diab H. [9] emphasizes that, after years of operation, oil – contaminated concrete can experience a 40-50% decrease in strength, with the greatest decrease observed in floor slabs. This is associated with the shape of the contact surface of structures.

Despite the significant number of studies indicating the negative impact of oils on concrete, some studies note that under conditions of short – term exposure to heavy oils, the reduction in strength may be insignificant. Rollo B. and Goshek Y. [13] note that the decrease in strength is only observed for three months. After this period, the strength stabilizes at a virtually constant level throughout the year. They also note that the extent of the decrease depends on the conditions of the concrete's initial hardening.

Additionally, there are scientific studies [10, 15] that suggest positive outcomes from various technological approaches to mitigating the impact of mineral oils on concrete. Research on protective coatings and special additives, for example, can help maintain concrete's resistance to the negative effects of petroleum products. This may include special repair methods and improvements to concrete mix composition.

Analysis of scientific publications shows that the influence of mineral oils on concrete strength is a multifaceted issue requiring further research, particularly regarding the development of methods to preserve the strength of structures in the event of prolonged contact with oils. Current research focuses on finding optimal materials and technological solutions that significantly increase the durability of concrete structures, even when they come into contact with petroleum products.

Setting goals and objectives. This study aims to investigate the impact of mineral oils on the physical and mechanical properties of heavy concrete, particularly its strength and average density. Additionally, the study seeks to identify the primary factors influencing these changes, including the type of oil, its condition (new or used), and the application method.

The research objectives include:

1. Assessing the effect of new and used mineral oils on concrete strength and density.

2. Comparing two methods of concrete interaction with oils (immersion and brush application) in terms of their effect on changes in concrete strength and density.

3. Analysis of changes in concrete's mechanical properties (compressive strength) after contact with different types of oils for varying lengths of time.

Materials and methods. The study aimed to investigate the effect of mineral oils on the mechanical properties of heavy concrete. The concrete cubes, which measured 100×100×100 mm, were made using Portland cement (PC II/A-B-500R-N, SEM II/A-LL 42.5 R), class C 32/40 (B40), river sand, crushed stone (5–20 mm), and water. The ratio of cement to sand to crushed stone to water was 1:2:4:0.5. The average cubic compressive strength of the control samples (without oil exposure) was 45.2 MPa after 28 days. Initial porosity (12.5%) was determined using the saturation and hydrostatic weighing method, in accordance with DSTU B V.2.7-170:2008. Water absorption (5.3%) was determined by the mass method in accordance with DSTU B V.2.7-170:2008. After exposure to mineral oils, the porosity of the samples decreased by an average of 1–2% when immersed and increased by 3–4% when applied with a brush. This is due to the oil partially filling or destroying the pores. Oil absorption was determined experimentally after contact. Samples were prepared and tested in accordance with DSTU B V.2.7-214:2009 "Concrete. Methods for Determining Strength Using Control Samples" and DSTU B V.2.7-170:2008, "Concrete. General Technical Conditions". The tests were carried out under standard conditions: a temperature of 20°C and a humidity level of 45%. Six types of mineral oils were selected for the study: T-1500 transformer oil (new and used), 10W-40 motor oil (new and used), and IGP-30 oil (new and used) (Table 1).

Table 1 – Mineral oils that interacted with concrete

Transformer T-1500 new	**Transformer T-1500 used**	**IGP-30 new**	**IGP - 30 spent**	**Engine oil 10W-40 new**	**Motor oil 10W-40 used**
					

In the study, the oils were used exclusively as external agents that interacted with the concrete. That is, the oils were not added to the concrete mixture, but rather, were applied to the surface of the samples by immersion or brush application. Therefore, the oils did not act as concrete additives or components, but rather simulated the conditions of concrete structures in contact with lubricants. The samples were kept in contact with the oils for 10 or 30 days. For the immersion method, the samples were fully submerged in oil in sealed containers. Brushing was performed daily. The thickness of the oil layer applied with a brush was approximately 0.5–1 mm, as determined by visual inspection and weighing the samples before and after application. The oils' effect was evaluated 10 and 30 days after contact with concrete. The physical and chemical characteristics of the oils used in the study are provided in Table 2. Waste mineral oils are lubricants that lose their original properties during operation, according to DSTU GOST 21046:2019 "Waste petroleum products. General technical conditions", DSTU 4058:2001 "Lubricating oils" and DSTU GOST 21046:2019 "Waste petroleum products. Terms and Definitions" and DSTU 2156-93 "Motor Oils. General technical conditions". These oils are characterized by the presence of oxidation products, metal impurities, and resinous compounds in their composition. The density (before and after the experiment), viscosity, and acid number were determined for each oil.

To assess the impact, measurements were taken to determine changes in average density and compressive strength. The average density of the samples was recorded before and after they came into contact with the oil using analytical scales. Strength was assessed using a standard compression test. Changes in properties were compared depending on the type of oil, whether it was new or used, and the application method. Each oil type was tested twice for each application method, and the results were analyzed using average values. Particular attention was paid to how the type of oil, method of application, and duration of exposure interacted to affect the mechanical properties of concrete.

Table 2 – Characteristics of mineral oils

Type of oil	Condition	Density before testing, g/cm³	Density after testing, g/cm³	Viscosity at 20°C, mm²/s	Acid number, mg KOH/g
Transformer T-1500	new	0.876	0.878	28	0.03
Transformer T- 1500	worked out	0.885	0.889	31	0.12
IGP-30	new	0.845	0.846	25	0.05
IGP-30	worked out	0.852	0.857	27	0.15
Engine oil 10W 40	new	0.874	0.875	90	0.04
Engine oil 10W-40	worked out	0.881	0.886	95	0.18

Research results. Concrete samples measuring 100×100×100 mm and made of Portland cement were used for the study. The samples were exposed to various types of mineral oils, including new and used T-1500 transformer oil, 10W-40 motor oil, and IGP-30 oil. The goal was to evaluate how oils affect the mechanical properties of heavy concrete, particularly its average density and compressive strength. To this end, two methods of oil application were employed: immersion of samples in oil and application of oil with a brush. The properties of the concrete were studied 10 and 30 days after contact with the oils.

The results demonstrated significant differences in concrete behavior depending on the type of oil, its condition (new or used), and the application method. According to the obtained data, the most significant effect on the change in concrete's average density and strength was observed when the samples were immersed in new T-1500 transformer oil. This oil exhibited the highest increase in bulk density and compressive strength after 10 and 30 days. Thus, 10 days after immersion, the average density of the samples increased by 1.14%; on the 30th day, it increased by 1.18%. This indicates the concrete structure actively absorbed the oil, likely contributing to a reduction in microcracks and an increase in the material's integrity. Conversely, applying oil with a brush did not cause significant changes in average density – only 0.05% after 10 days and 0.80% after 30 days – indicating superficial oil penetration.

The best results in terms of compressive strength were recorded when the samples were immersed in new T-1500 transformer oil. After 10 days, the samples' strength increased by 4.14%, and after 30 days, it increased by 13.06%. This is the highest increase among all types of oils. This indicates the positive effect of this oil on concrete's structural strength, particularly due to the oil partially filling the pores and reducing internal defects in the material. In contrast, using the brush application method decreased concrete strength: by 4.86% after 10 days and by 48.12% after 30 days. This indicates the oils' uneven and superficial effect on concrete.

Similar results were observed when using used T-1500 transformer oil. The change in average density of the samples after 10 and 30 days was similar to the results for new oil; however, the change in compressive strength was significantly lower. Specifically, the strength increased by 0.92% after 10 days and by 2.14% after 30 days. This indicates the limited effect of used oil containing oxidized products and contaminants, which can reduce the positive effect. Additionally, applying the oil with a brush caused a slight decrease in strength: 0.80% after 10 days and 6.57% after 30 days. This demonstrates the negative effect of used oil on concrete when using the surface application method.

A study of the effect of IGP-30 oil showed a lower ability to penetrate concrete compared to transformer oil. In particular, 10 days after immersion, the average density of the samples increased by 0.70%, and after 30 days – by 1.12%. Applying the oil with a brush led to a slight decrease in average density due to moisture evaporation from the concrete surface: 0.19% after 10 days and 40.35% after 30 days. At the same time, the strength of the samples increased by 2.71% on day 10 and by 12.19% after 30 days, confirming the positive effect of IGP-30 oil on concrete strength (Fig. 1), although less pronounced compared to T-1500 transformer oil.

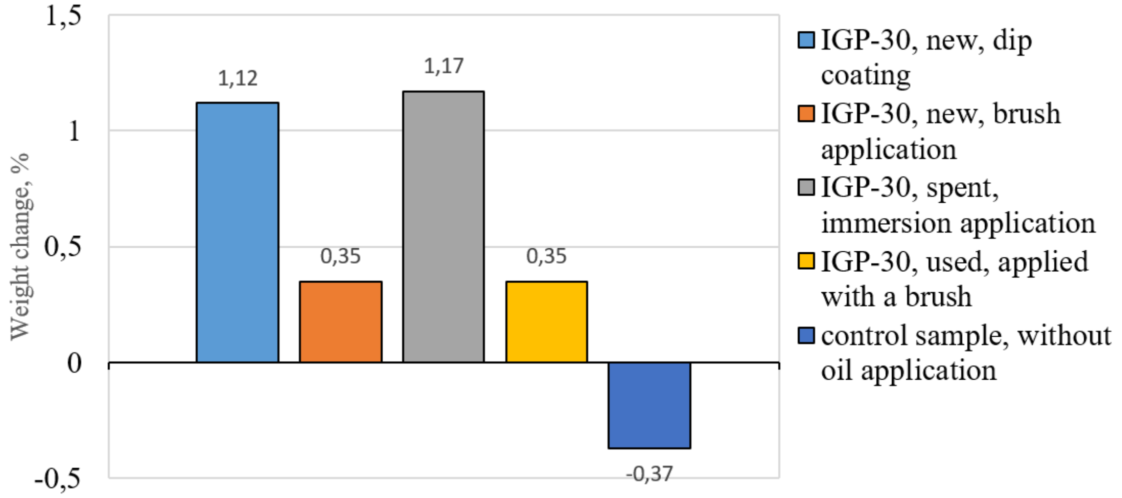

Fig. 1. Change in the average density of a concrete sample after interaction with IGP-30 oil (30 days relative to 1 day)

Opposite results were observed when using used IGP-30 oil. On the 10th day after immersion, the samples showed a decrease in strength by – 2.40%, and on the 30th day, this figure was – 4.88%. The greatest decrease in strength on the 30th day was recorded when applying the oil with a brush, which led to a decrease in strength by 84.11% (Fig. 2), which is the worst result among all the options studied.

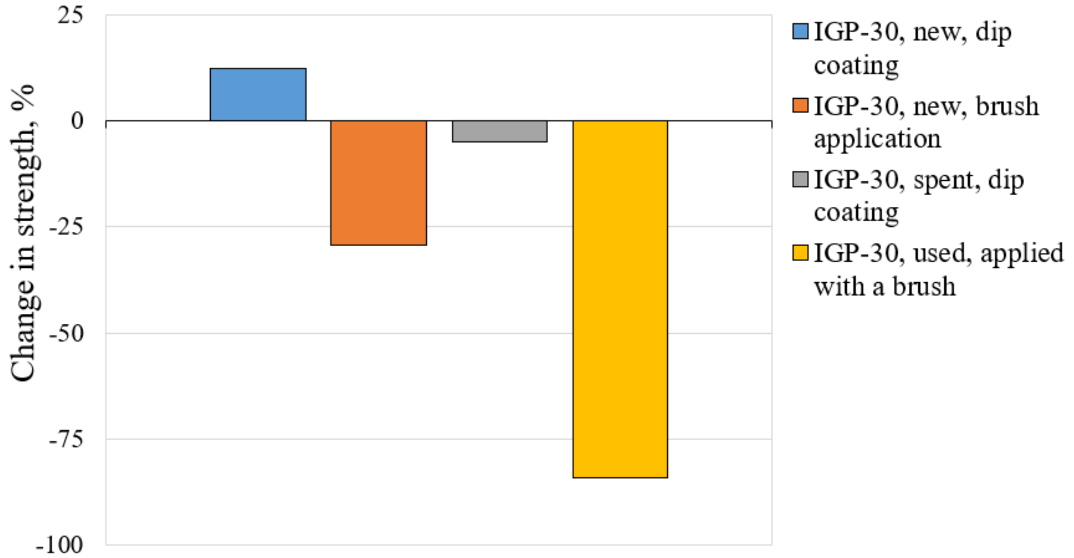

Fig. 2. Change in compressive strength of concrete sample after interaction with IGP-30 oil (30 days relative to 1 day)

As for 10W-40 motor oil, 10 days after immersion, the average density of the samples increased by 0.74%, which is an average indicator compared to other oils. At the same time, changes in compressive strength on day 10 showed a significant decrease of – 7.47%, which is the worst result among all new oils. The level of destruction is shown in the photo (Fig. 3).

Fig. 3. Destruction on day 10 of a sample immersed in new 10W-40 motor oil

However, 30 days after immersion, the strength increased by 11.41%, indicating the possibility of compensating for the negative effect under conditions of prolonged contact with oil. At the same time, applying oil with a brush caused a significant decrease in strength by – 63.74% (Fig. 4), which is another confirmation of the negative effect of surface application of oils.

Fig. 4. Destruction of the sample after 30 days following the application of used motor oil 10W-40 with a brush

The worst result for used 10W-40 motor oil was observed after immersion, when after 30 days the strength decreased by – 11.04%. This confirms the negative impact of used oils on concrete during prolonged contact. The least impact was recorded when the oil was applied with a brush, where the strength decreased by only – 0.25% after 10 days and – 55.07% after 30 days.

Visual observations revealed the formation of a film and deposits on the concrete surface after contact with waste oils. The depth of oil penetration into the concrete structure was estimated from sample cuts and amounted to 5–7 mm when immersed and 1–2 mm when applied with a brush.

Overall, the results of the study confirm the importance of correctly applying oil to preserve concrete's strength. Immersing samples in oil produced significantly better results than applying oil with a brush. New oils, particularly transformer oil T-1500, had the most positive effect on concrete samples. Waste oils, especially IGP-30 and 10W-40 motor oil, had a significantly negative effect, particularly when applied with a brush. This indicates the importance of using high – quality materials and methods to preserve concrete strength when it is in prolonged contact with oils.

Analysis of the results also highlights the importance of further research on the effects of other types of oils and different exposure conditions for a more accurate understanding of the mechanisms of interaction between oil and concrete, which will allow the development of more effective strategies for improving the properties of concrete under various aggressive influences.

Research on the impact of mineral oils on concrete's mechanical properties has revealed that this effect hinges on the oil's type, condition (new or used), and application method. Immersing concrete samples in oil increases their average density, indicating that the oil penetrates the concrete's pores [6]. New oils, especially transformer oil, are more effective at increasing average density than used oils due to their homogeneous composition.

The effect on concrete strength was mixed: immersion in new oil increased strength, while used oils, in particular IGP-30 and motor oil, had a negative effect. This can be explained by chemical changes in used oils that contribute to concrete degradation. The brush application method often led to a decrease in strength due to uneven oil distribution.

To reduce the negative impact on concrete, it is recommended to use new oils and the immersion method for uniform saturation. To protect concrete structures, special coatings that reduce oil permeability should be developed [8]. Further research is needed to study the long – term effects and develop technologies that protect concrete from aggressive environments, such as mineral oils.

Conclusions. Research into the effect of mineral oils on the mechanical properties of heavy concrete has revealed key factors influencing changes in the structure of the material under the action of chemicals. The type of oil, its condition (new or used), and the method of application have a significant impact on concrete properties such as average density and compressive strength.

The new T-1500 transformer oil showed the best results, increasing the average density and strength of concrete, especially with the immersion method. After 30 days, strength increased by 13.06% and average density by 1.18%. Used transformer oil had a lesser effect due to the presence of oxidation products, which reduced the effectiveness of interaction with concrete. The new 10W-40 motor oil initially reduced the strength of concrete by 7.47%, but after 30 days, the positive effect increased to 11.41%. At the same time, used oil showed a significant decrease in strength when applied with a brush (a decrease of 55.07%). IGP-30 oil had a moderate positive effect when immersed (strength increased by 12.19%), while used oil applied with a brush caused a significant decrease in strength (- 84.11%), indicating the negative impact of oxidation products. The immersion method showed the best results, ensuring uniform saturation of the concrete, while brush application, especially with used oils, led to local damage to the concrete due to uneven oil distribution. Over time, after 30 days, the new oils contributed to improving the characteristics of the concrete, while the used oils caused a decrease in strength. The difference between new and used oils is due to their chemical composition: new oils have a more stable composition, while used oils contain resins and oxidation products that destroy concrete. The results obtained are consistent with the requirements of DSTU B V.2.6 - 156:2010, which stipulate increased density (not less than 2400 kg/m^3), low water absorption (up to 5%), and resistance to aggressive environments for concrete used in oil tanks. The samples that were in contact with the new T-1500 transformer oil met these indicators, confirming the suitability of heavy concrete for use in lubricant tanks, provided that the materials and oil application methods are correctly selected. Overall, the results of the study help to better understand the mechanisms of interaction between mineral oils and concrete and may be useful for improving construction technologies.

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ДОСЛІДЖЕННЯ ВПЛИВУ МІНЕРАЛЬНИХ ОЛИВ НА МІЦНІСТЬ І СЕРЕДНЮ ГУСТИНУ ВАЖКОГО БЕТОНУ

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Анотація. У статті досліджено вплив мінеральних олив на міцність і середню густину важкого бетону. Важкий бетон є основним матеріалом у будівництві, що використовується для створення конструкцій з підвищеними вимогами до міцності та стійкості, однак вплив хімічних агентів, таких як мінеральні оливи, на його властивості залишається недостатньо вивченим. Вивчення цього аспекту є важливим для покращення довговічності і безпеки бетонних конструкцій, зокрема тих, що піддаються впливу олив в умовах промислових процесів чи аварій.

Метою дослідження було вивчити, як різні типи мінеральних олив (трансформаторна олива Т-1500, моторна олива 10W-40, ІГП-30, як нові, так і відпрацьовані) впливають на фізико-механічні характеристики важкого бетону, зокрема його міцність і середню густину. Експерименти проводились на бетонних зразках розмірами 100×100×100 мм, виготовлених з портландцементу, за стандартних умов збереження. Оливи наносились двома методами: зануренням зразків у оливу та нанесенням пензликом.

Результати досліджень показали, що найістотніший вплив на міцність і середню густину бетону мав метод занурення зразків у нову трансформаторну оливу Т-1500, де через 30 днів спостерігалось значне збільшення середньої густини на 1.18% та міцності на стиск на 13.06%. Застосування відпрацьованих олив та метод нанесення оливи пензликом призводили до зниження міцності бетону, зокрема при використанні відпрацьованої моторної оливи 10W - 40 на 30 день міцність знизилась на 63.74%. Водночас нанесення оливи пензликом викликало переважно поверхневі зміни, без значних поліпшень або навіть зниження міцності бетону. Результати підтвердили, що тип оливи, її стан та метод нанесення мають суттєвий вплив на механічні властивості бетону. Дослідження вказує на важливість вибору методів захисту бетонних конструкцій від негативних впливів хімічних агентів і відкриває перспективи для подальших досліджень у цій галузі, зокрема розробки технологій, які знижують вплив мінеральних олив на довговічність та міцність бетону.

Ключові слова: важкий бетон, мінеральні оливи, міцність бетону, середня густина, механічні властивості бетону.

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