THE ROLE OF ENGINEERING UNITS IN THE BATTLE FOR MARIUPOL, 2022*

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Abstract: The Battle for Mariupol was one of the most intense and significant engagements to date in the Russian–Ukrainian armed conflict. Its course and outcome were significantly shaped by the activities of engineering units on both sides. Ukrainian forces, through the execution of tasks within the scope of engineering and counter-engineering operations, provided support to complex defensive tactical actions. Prominent examples include the emplacement of artificial obstacles, with minefields having particularly extensive application, as well as the fortification of natural and artificial features, notably the adaptation of existing industrial facilities such as the Azovstal industrial complex. Russian forces applied a modified siege tactic by destroying infrastructure and, through the execution of tasks related to obstruction, constructing various obstacles to prevent maneuver and supply. In order to support maneuver and achieve the tempo of the offensive of their own forces, they employed engineering units in tasks related to overcoming obstacles, while not omitting the execution of fortification tasks under newly emerged conditions.

The aim of examining these activities was to assess their effects on the conduct of the military operation, as well as the subsequent consequences for the civilian population. The paper presents the results of the research through the analysis of available open sources and their comparison with prior knowledge of the doctrinal application of engineering units in contemporary warfare in the states concerned

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(analyzed through the lens of the doctrine governing the employment of engineering units of the Serbian Armed Forces), positive solutions for one's own forces and the consequences imposed on the adversary, as well as the humanitarian consequences of this battle for the civilian population. This paper seeks, through analysis, to examine the roles of engineering units in the Battle for Mariupol, with an emphasis on their importance in the creation and destruction of defensive structures, the use of infrastructure, and the possibilities for improving the tactics of employing engineering units that influenced the outcome of the battle. In addition, attention is directed toward examining the impact of modern weapons systems and combat systems on the conduct of operations and the achievement of objectives.

Keywords: *Mariupol, engineering unit tactics, defense, siege, humanitarian consequences*

Mariupol and the Significance of Its Location

Mariupol is located in southern Ukraine, on the coast of the Sea of Azov, and its geographical position confers a significant geopolitical and economic role within the region. The city is known for its industrial strength, particularly due to large metallurgical complexes such as "Azovstal" (Rus. Азовсталь) and the Ilyich Iron and Steel Works. These industrial giants not only contributed to the economy of Ukraine but also provided strategic resources for military needs, namely metal required for the production of armaments. Large-scale production significantly influenced export capacity as well.

The location of Mariupol also enabled its development as an important transportation hub, as it represents a key link between the southern part of Donbas and the Crimean Peninsula, which makes it strategically important not only for the economy of Ukraine but also for the military plans of the region. Its position on the coast of the Sea of Azov enables control over maritime access and opens routes for further operations toward Odesa and the broader Black Sea region.

Due to its position and significance, Mariupol became one of the primary objectives in the wartime efforts of Russian forces during the initial phases of the special military operation. By establishing control over the city, the armed forces of the Russian Federation would be enabled to establish a land corridor connecting Crimea with areas under the control of pro-Russian forces in Donbas. This course of action was of key importance for establishing stability in the area and achieving full control of access to the Sea of Azov, as well as for preparing the ground for potential further advances in other parts of the territory of Ukraine.

From the outset of the conflict, Mariupol was a target of attacks by Russian forces, which led to extensive destruction of the city. In addition to its industrial and geostrategic significance, the city also became a symbol of resistance for Ukrainian forces, which offered fierce resistance during the fighting for Mariupol. The tactics employed by Russian forces, which have not changed significantly since the Second World War, resulted in the destruction of infrastructure and a large number of civilian casualties, as well as the formation of deep geopolitical front lines that determined the course of the special operation in southeastern Ukraine.

The battle began in late February and lasted until May 2022. Russian forces, with the support of the self-proclaimed Donetsk People's Republic (DPR), encircled the city, cutting supply lines in order to compel the defenders to surrender. This led to a prolonged siege that resulted in the destruction of a large part of the city. Through the activities undertaken in both defense and attack, this battle represents one of the most dramatic examples of urban warfare during the Russian–Ukrainian conflict.

The Battle for Mariupol left a profound impact on the civilian population. The city was practically completely destroyed, and civilians were exposed to extreme living conditions, without basic necessities such as water, electricity, and medical assistance (The Asahi Shimbun, 2022). The destruction of infrastructure, partly caused by engineering units, further aggravated the situation, thereby additionally worsening already difficult living conditions. The consequences of this destruction significantly contributed to the existing humanitarian catastrophe, endangering the lives and survival of the population (Human Rights Watch, 2023).

The Role of Engineering Units in Combat Operations in Mariupol

Based on numerous reports on the consequences observed during the Battle for Mariupol, it can be concluded that engineering units had a significant (if not key) role in the planning and execution of military operations by both sides during the battle. By examining the activities of engineering units of the parties to the conflict, conclusions can be drawn that could significantly influence considerations regarding the assessment of existing capacities and capabilities of engineering units in the contemporary operational environment. Analyzing engineering and counter-engineering activities through the prism of the doctrinal views of the Serbian Armed Forces, it can be concluded that engineering units are the main executors of tasks within the framework of engineering operations in the Land Forces (Doctrine of the Serbian Land Forces, 2011: 46). The basic content implemented during engineering operations is obstacle emplacement, while within counter-engineering operations the content includes overcoming obstacles, road preparation, fortification, and the neutralization and destruction of enemy engineering units (Doctrine of the Land Forces, 2011: 46–47). By executing obstacle emplacement tasks, "losses are inflicted on the enemy and its movement and maneuver of forces are prevented, slowed, and channeled" (Doctrine of the Serbian Armed Forces, 2010: 51).

Obstacle emplacement, as the basic content of engineering operations, is carried out through the construction of various types of obstacles. Obstacles created through the use of mine–explosive means are particularly relevant in contemporary operations. The action of explosives causes the physical destruction and disabling of combat equipment (especially armored and mechanized assets) and enemy personnel. Rubble created as a result of explosive effects enables the slowing, stopping, channeling, or prevention of further movement of the enemy along a selected (assessed) direction (Military Lexicon, 1981: 704).

According to their tactical purpose, method, and time of construction, obstacle emplacement may be “primary and supplementary” (Regulation on Obstacle Emplacement and Overcoming Artificial Obstacles, 1981: 14). During the planning and execution of a defensive operation, the main emphasis is placed on the construction of various types of artificial obstacles: mine–explosive, fortification, obstacles created as a consequence of the destruction of lines of communication, the demolition of structures on lines of communication, incendiary obstacles, obstacles created by flooding terrain, and chemical and radioactive obstacles (Milić, A., 2016).

Counter-engineering operations represent a set of measures, actions, and activities by which the effects of enemy engineering and other actions are reduced, while favorable conditions for combat operations, movement, and maneuver are created for one’s own forces (Milić, A., 2024). They are conducted by all units for their own needs and in accordance with their capabilities; however, at the main effort of combat operations, engineering units are employed, with the support and coordination of the primary executors of operations: infantry, armored units, artillery units, and aviation (Doctrine of the Serbian Armed Forces, 2010: 51).

Overcoming obstacles encompasses the undertaking of necessary measures and activities aimed at the destruction and neutralization of mine–explosive obstacles (hereinafter MEO) and other artificial obstacles, the forced crossing and passage over water and dry obstacles, and the organization of control and protective services (Kitanović, R., 2000: 31). Overcoming obstacles (natural and artificial) is undertaken in order to create the necessary conditions for the successful maneuver of units, to ensure the movement of units, to prevent losses on mine–explosive and other obstacles, and to create the necessary conditions for ensuring the continuity of supply and evacuation in combat zones (Milić, A., 2024).

Fortification represents the purposeful arrangement (adaptation) of terrain with the aim of creating: favorable conditions for fire action, observation, and command; more complete protection of personnel and materiel from the effects of enemy fire; safer and more protected movement on positions (along the front and in depth); and conditions for the concealed deployment of one’s own forces from ground and aerial observation (Milovanović, D., 1979: 4). It is achieved through the construction of facilities for fire action (of branch and service units), observation, command, movement, and protection, or through the adaptation of natural and artificial features on occupied and unoccupied positions of units on the terrain (Milić, A., 2024).

Road preparation encompasses the maintenance, repair, and reconstruction of existing roads, as well as the construction of new roads, takeoff and landing surfaces, piers, and camouflage mooring points (Kitanović, R., 2000: 45). Road preparation for the passage of combat elements of units includes their most essential enabling. More permanent road repair is undertaken to ensure uninterrupted traffic of a certain speed and capacity for maneuver from depth, supply, and evacuation. Road maintenance подразумева bringing individual routes of axial and lateral (roaming) type into continuous and functional use by removing (eliminating) obstacles created by enemy action, damage, or increased capacity requirements and higher traffic frequency along a given route. The construction of roads for short-term use implies the construction of so-called temporary military roads for the movement and maneuver of combat elements of units, supply, and evacuation of limited capacity and temporary character. The construction of roads for permanent use implies the construction of roads according to specific projects and plans, with greater engagement of engineering forces and resources over a longer period. Such roads are most often constructed in peacetime and in conditions of imminent war danger, and more rarely during a special operation (Milić, 2024). Road repair and reconstruction include the removal of damage incurred on roads caused by enemy action, prolonged use, or natural causes (rockfalls, landslides, ground subsidence). The number of roads that need to be prepared and maintained in a given zone depends on the task, the concept of operations, the development and condition of the road network, the available time, the capabilities of road units, and enemy activity.

For Ukrainian forces, the role of engineering units was crucial in the organization of the city's defense. They employed engineering unit resources to construct defensive structures (which were interconnected by trenches and lines of communication) (Figure 3) and to reinforce them with various types of mine–explosive and fortification obstacles in order to slow the advance of Russian military forces. Minefields and groups of mines were emplaced along key lines of communication, which constituted an additional obstacle for Russian forces (Kelly, L., 2022).

Access routes to key lines of communication were also mined in order to further slow Russian units and prevent lateral redeployment of forces. Ukrainian engineers emplaced various types of mines, primarily anti-personnel and anti-tank mines, while also employing different types of improvised explosive devices and booby traps in tactically important zones. This enabled units within the city to retain control over certain areas longer than initially expected. Along certain axes, the demolition of infrastructure facilities was carried out in order to create obstacles and prevent movement. Within structures that provided good observation over particular lines of communication, fortification measures were undertaken to create strongpoints that would further hinder the penetration of Russian forces along specific routes and directions. Of particular importance was the fortification of positions around the "Azovstal" plant, where strong Ukrainian forces were located. This example of how existing infrastructure can be utilized to fortify a strongpoint (Perrya, 2022) will be studied for a long time.

The "Azovstal" plant (Rus. Азовсталь), one of the largest industrial complexes in Ukraine (Azovstal. Metinvestholding, 2013), provided a significant tactical advantage to Ukrainian forces. In addition to its above-ground structures, Azovstal also possessed a network of underground tunnels that enabled soldiers and civilians to shelter from artillery and air attacks (Perrya, 2022).

The underground facilities were well adapted for the storage of supplies, including food, water, and medical equipment, which enabled Ukrainian forces to maintain their positions for a longer period. The underground structures of the "Azovstal" complex were not constructed as part of military infrastructure, but rather as an integral component of an industrial complex from the Soviet era (Perrya, 2022). The approach to the construction of important facilities during the period of Soviet dominance is illustrated by the fact that the complex includes a multilayered network of tunnels and chambers at depths of up to 30 meters below ground. The tunnels were used for the transport of materials during the operation of the plant, but were also designed to be resistant to air strikes and explosions in the event of military conflict or nuclear attacks. Thick reinforced concrete and steel structures make these tunnels exceptionally robust. These underground structures became shelters for a large number of civilians, who found refuge there from armed actions. Engineering units of the Ukrainian Armed Forces adapted the facilities within the complex not only for defense during the siege but also for humanitarian purposes. Tunnels that were used for troop movement and the establishment of ambushes were transformed, through the emplacement of explosives, into lines of resistance deep within the complex for defensive purposes. This network of tunnels enabled maneuver and rapid withdrawal, thereby preventing Russian forces from easily entering the complex. The facilities were used for the storage of ammunition, food, water, and medical equipment, ensuring the survival of the defenders.

In situations where withdrawal from positions was necessary, the Ukrainian military carried out the mining of various facilities, not only those of military but also of civilian purpose. Through such mining, particularly when combined with booby traps and improvised explosive devices, a sense of insecurity was created for Russian forces at every step. In this way, the advance of Russian forces was significantly reduced, providing Ukrainian forces with additional time to consolidate their defenses and prepare fires on defined positions. These efforts by engineering units were aimed at prolonging the resistance of forces stationed in the city, inflicting losses, and weakening the offensive power of Russian forces.

Various types of anti-tank ditches were widely deployed, forming physical barriers that impeded the advance of heavy mechanized assets. In addition, in order to further complicate movement along key lines of communication within the city, anti-tank tetrahedrons, concrete barriers, and other improvised objects were emplaced. These obstacles were further supplemented by obstacles created through demolition, as critical infrastructure facilities were prepared for demolition and destroyed in order to prevent or slow the movement of Russian forces. Based on experiences from the NATO aggression against the Federal Republic of Yugoslavia in 1999, the question arises as to the justification of creating obstacles through the demolition of infrastructure facilities, since, at the end of a conflict, the consequences in conflict-affected areas are borne primarily by the civilian population.

In addition to military assets used for the construction of obstacles, Ukrainian forces also employed civilian construction machinery—excavators, cranes, loaders—as well as civilian companies for the construction of fortification obstacles. The justification for the use of civilian construction machinery is conditioned by the performance of the equipment (Božanić et al., 2021: 3). It is particularly important to highlight the capabilities of machinery used in surface mining operations or large processing facilities.

On the other hand, Russian forces employed engineering units to overcome detected obstacles and to create obstacles aimed at preventing the penetration of Ukrainian forces, particularly minefields with depths exceeding 100 meters and in some cases up to 500 meters. This significantly complicated demining tasks for Ukrainian forces (Axe, D., 2023) as well as the supply of encircled units, and was also used for the destruction of urban infrastructure in order to create conditions for penetration and to weaken defensive capabilities. To achieve these objectives, explosives and heavy machinery were used to destroy industrial facilities, power substations, and water supply systems (The Asahi Shimbun, 2022). The intent was to weaken the defensive capability of Ukrainian forces and to exert pressure on both military personnel and the civilian population of the city, placing them in severe living conditions, thereby reducing support for resistance and accelerating surrender (Human Rights Watch, 2023).

The intent to reach specific lines and positions was conditioned by the assigned tasks of detecting mine–explosive obstacles, creating passages through them, and their subsequent clearance. An additional challenge for Russian engineering units was the ingenuity (cunning) of Ukrainian forces in the construction of mine–explosive obstacles, drawing on the knowledge of instructors from other states. In addition to newly emplaced mine–explosive obstacles, minefields laid in previous decades also posed a problem. These tasks were addressed by engineering units of the sapper specialty through the employment of new explosive-based demining systems (e.g., the UR-77 "Meteorit") (Newdick, Th., 2023).

In order to ensure the tempo of the attack and provide support to unit maneuver, pontoon units responsible for the deployment of pontoon bridges over water obstacles came to the fore. The pontoon bridge parks with which Russian pontoon units have been equipped over recent decades have been significantly improved, particularly in terms of load capacity and the width of obstacles that can be overcome with a single set. The load-bearing capacity of pontoon bridges has been increased, enabling the construction of bridges of the 120-ton class (Milojević et al., 2009: 5). These bridges are generally constructed at the level of combat groups and assigned to support operations (Royal United Services Institute for Defence and Security Studies, 2023). Regardless of these positive practices (speed of deployment, width of the obstacle overcome, bridge load capacity), it is necessary to critically point out serious shortcomings observed during the planning and organization of bridge crossing sites, particularly with regard to air support and the application of camouflage discipline measures (Milić et al., 2023: 3).

In addition to the above, engineering units played a significant role in overcoming various obstacles and organizing logistical support for the Russian offensive. Through the construction of temporary bridges, the removal of rubble, and the creation of temporary roads, engineering units of the Russian forces created the necessary conditions to ensure faster and safer movement (maneuver) of their own units toward the central parts of the city. These activities enabled them to establish a firm siege around the city, thereby significantly controlling the situation and disrupting the supply of Ukrainian defenders.

Engineering units of the Russian military also constructed various types of siege-oriented obstacles around Mariupol, thereby preventing Ukrainian forces from leaving the city as well as the delivery of supplies from other areas. These blockades included the systematic emplacement of concrete barriers, reinforced concrete obstacles, steel barbed wire, destroyed vehicles, and other obstacles intended to prevent any movement into or out of Mariupol. One method for the rapid construction of obstacles involved providing engineering units with artillery–rocket systems capable of remote mining, which enabled the emplacement of minefields at distances of up to 15 km (Milić et al., 2009: 3). In this way, minefields could be emplaced within a short time frame deep inside the disposition of Ukrainian forces, directly affecting maneuver and supply.

Despite being the attacking side, Russian forces did not neglect the fortification of seized positions and lines. Fortification was conducted according to methodologies dating back to the Cold War period, which proved effective in this situation. Russian defensive positions generally consist of two to three lines, depending on the situation (Figure 5). The first line, extending along the line of contact, includes combat positions occupied by infantry. The second line consists of properly constructed trenches—compared to foxholes in the first line—and concrete firing positions where feasible. In front of these positions, several belts of obstacles were emplaced, usually formed by anti-tank ditches approximately 4 m deep and 6 m wide, dragon's teeth, and entanglements of wire obstacles. Trench positions are typically structured as company-level defensive positions with constructed shelters and placed along ridge lines so as to provide fire coverage over the front. The depth of the defensive line is usually about 5 km from the first line, and each belt of physical defense tends to extend between 700 m and one kilometer, ensuring that the entire obstacle system is covered by fire. The third line generally includes reserve combat positions and concealed areas for various reserve forces, with dug-in vehicle positions. Meanwhile, command posts tend to be underground and reinforced with concrete. The overall depth of defensive fortifications along certain axes exceeds 30 km (Watling, J., & Reynolds, N., 2023).

Through the construction of fortification structures, engineering units further contributed to the survivability and protection of units during combat operations. By constructing facilities with heavy overhead cover or in combination with the fourth level of fortification (Milovanović, D., 1979: 4), which were built with the full application of camouflage protection measures, the survival time of soldiers on the battlefield was extended.

Tactical Experiences from Operations in a Contemporary Combat Environment

The possibilities for the application of modern systems and technological advancements came to the fore to a significant extent during the Ukrainian–Russian conflict. The employment of new capabilities substantially influenced changes in the previously established methods of engaging units and assets. This conflict imposed the need to consider future steps based on what was applied and the manner in which specific actions were executed.

The situation faced by the Ukrainian military in the Mariupol area required the identification of new solutions. The possibility of employing drones for transport tasks (Milić, A., et al., 2018: 5) enabled the delivery of supplies (Axe, 2022). The United Kingdom donated a large number of transport drones to Ukraine, "which can be used to supply food, water, and ammunition for small-caliber weapons" (Axe, D., 2022), thereby placing them among the principal elements supporting warfare in an urban environment. Such practices have demonstrated that the dynamics of conflict are rapidly changing and that, for the purpose of blocking (besieging) populated areas, it is necessary to plan, organize, and implement control of the airspace at low altitudes.

The aforementioned example of drone employment is not an isolated case. From the beginning of the conflict on the territory of Ukraine, and later in Russia, drones have played a key role in strategic and even engineering operations conducted by Ukrainian forces. From the outset of the conflict, the Ukrainian military demonstrated significant innovation in the use of drones, which assisted in numerous engineering operations. Drones were one of the key tools in the Ukrainian arsenal for intelligence gathering, through terrain reconnaissance, assessment of enemy force strength and possible avenues of movement, as well as for identifying locations where obstacles needed to be emplaced or various actions conducted.

The advantages of drones also became evident in situations requiring precise determination of the placement of explosive devices and mines. In addition to obstacle emplacement, drones assisted in assessing damage to infrastructure and identifying locations that required urgent repairs or additional defensive measures (New York Times, 2024). Experience gained in delivering small quantities of ammunition, equipment, and medical supplies in Mariupol was leveraged for the rapid delivery of limited quantities of ammunition, equipment, and medicines along the front line, particularly in remote or hard-to-access areas. This form of logistical support proved especially important in situations where traditional transport routes were under threat or blocked (New York Times, 2024).

The ability of drones to carry a certain payload was also exploited as a means of delivering explosives or rockets, enabling Ukrainian forces to destroy key Russian logistical nodes and equipment, as well as to conduct attacks on enemy defensive lines. This employment of drones as weapons significantly accelerated the removal of obstacles that impeded the advance of Ukrainian forces.

After major battles, Ukrainian forces used drones to rapidly assess damage to infrastructure (damage and destruction to lines of communication and structures along them, as well as to key facilities for the protection of personnel and mobile assets) and to determine which areas of terrain and facilities required urgent repairs or reconstruction.

The future of drones in the operations of Ukrainian engineering units lies in autonomous and robotic systems. Ukrainian forces are already working on the development of drones and robotic systems capable of independently performing complex tasks, such as the detection and removal of mines or the construction of defensive positions (MILITARNYI, 2025).

The approach to the employment of drones in combat operations has not been neglected by Russian forces either. It is a fact that at the beginning of the conflict these assets were used less extensively compared to Ukrainian forces; however, over time they increasingly found application in the execution of engineering operations as well. Initially, they were used for observation and data collection on terrain and facilities, employing systems equipped with thermal sensors and high-resolution cameras. Similar to Ukrainian forces, Russian forces employed drones to reconnoiter areas intended for mining. This system enabled faster identification of key routes and strategic locations where Ukrainian forces could establish defenses. In Mariupol, Russian forces used drones to reconnoiter areas around the city in order to identify possible axes of advance of Ukrainian forces. Based on the collected information, the Russian military emplaced significant quantities of explosives at locations such as bridges, supply routes, and access roads to the city, thereby influencing the further course of the operation. At the same time, these drones were used to detect obstacles emplaced by Ukrainian forces in order to neutralize or avoid them.

During movement within buildings, mini-drones were used for prior reconnaissance and observation of interior spaces in order to detect booby traps, strongpoints, or snipers at specific locations. In this way, a change was imposed on the previous tactics of clearing buildings and enclosed spaces.

The Russian military also actively used drones capable of carrying small payloads and employed them for the precise destruction of various structures, such as trenches and concrete barriers. Due to their equipment with modern electro-optical systems, these drones were also used for rapid inspection of damaged bridges, the condition of riverbanks, and road networks. Russia’s advantage in the research and development of robotic and autonomous drones, which were capable of independently performing complex tasks, became evident during the planning and execution of attacks on enemy supply lines, mine detection, and the conduct of counterattacks against Ukrainian drones, attacks on small mobile Ukrainian sensors or cameras, and strikes against Ukrainian force positions without human intervention. These systems proved useful in controlling the airspace and in countering Ukrainian drones that were transmitting data or conducting attacks (Leonova, J., & Fedorov, A., 2024).

With the intent of accomplishing tasks related to the creation of passages and the removal of mine–explosive obstacles within a shorter time frame, the employment of new types of explosives by engineering units of the Russian forces was observed, which to a considerable extent deviated from standard ones. Due to their power and effects (the consequences of demolition resulting from the employment of the UR-77 “Meteorit” system), they attracted significant global attention (Beckhusen, R., 2014). Although this system is used over large areas, the effects it produces are not easily explained. The only explanation reached by foreign analysts relates to the type of explosive employed within the system. In smaller areas, the Ukrainian military, during withdrawal, mined various facilities, not only those of military but also of civilian purpose. The resulting threats imposed new tasks on Russian forces that required the engagement of specialized sapper units. In accordance with procedures, after the seizure of territory, activities related to area reconnaissance and demining were undertaken. Various technical means were used for the detection and clearance of explosive devices, including the robotic complex “Uran-6” equipped with plows of different types, as well as service dogs. This robotic system has been employed since 2020, for example, in Chechnya, Syria, and Nagorno-Karabakh.

In situations requiring close support to combat arms and the execution of demining tasks or obstacle construction, engineering units of the sapper specialty are equipped with specialized engineering vehicles IMR-2 (equipped with a system enabling remote control) or IMR-3M (a combat engineering obstacle-clearing vehicle based on the chassis of the T-90 main battle tank). These assets reduce the time required to create passages through detected mine–explosive obstacles and enable the rapid removal of barriers made of tetrahedrons or other types of obstacles. During employment, personnel are protected within armored hulls. In situations where personnel survivability is critical, the vehicle is directed to a designated location and along a defined axis via remote control to execute assigned tasks, while operators control the system from a safe distance.

In order to prevent the advance of Russian units, Ukrainian units constructed various obstacles on lines of communication, most often through the demolition of road sections or the destruction of bridges and culverts, as well as by blocking certain sections with rubble. To overcome these obstacles, engineering units of the Russian military employed road-construction machinery and other specialized equipment used for clearing debris and creating passages.

Destroyed road sections or bridges were overcome using heavy mechanized bridges (for obstacles up to 40 m in width) or launch-type bridge structures. In cases where a destroyed bridge spanned a river wider than 40 m, pontoon units were engaged to construct pontoon bridges. With their assistance, crossings were restored or newly organized, enabling units to continue movement. After the establishment of bridgeheads and the seizure of territory under control, pontoon bridges were used not only for the crossing of military equipment but also for the delivery of humanitarian supplies and the rotation of units. In addition to pontoon units, other engineering units were also involved in the restoration of transport infrastructure, in accordance with the tempo and dynamics of combat unit movement. At destroyed facilities, activities first focused on locating and neutralizing emplaced mines, after which repair works commenced (Vojni pregled, 2022).

The previously described characteristics of an urban area, in which units operated both above and below ground, significantly complicated the organization of both offensive and defensive actions. In order to secure the disposition of their own units, engineering units of the Russian forces formed specialized engineering teams tasked with destroying entrances to underground tunnels and sewer openings by filling them in, which had a significant impact on the morale of the defenders. One method of further worsening the situation for besieged forces—identified both during the conflict in Ukraine and in the Gaza Strip (after 7 October 2023) (Arranz, A., et al., 2023)—is the systematic destruction of buildings, various facilities, and positions used for the accommodation of Ukrainian forces.

Particular attention to the employment of engineering units during analyses of the conflict on Ukrainian territory has been given by the United Kingdom's Royal United Services Institute for Defence and Security Studies. In its analyses, it states that "engineering is perhaps one of the least discussed elements of Russian forces during the invasion of Ukraine. Unlike most Russian forces, its engineers have performed well. The noted speed with which Russian infantry digs in, as well as the scale at which they improve their combat positions, is noteworthy and is complemented by combat engineering. Two engineering companies are assigned to each brigade, one focused on mining and the other on fortification and force protection" (Watling, J., & Reynolds, N., 2023).

The activities of engineering units had a decisive impact on the course of the Battle for Mariupol, contributing to a siege that exhausted Ukrainian forces and affected the civilian population in the city, while on the other hand enabling Russian forces to establish secure conditions for the conduct of the siege.

Conclusion

The Battle for Mariupol demonstrated the significance of the role that engineering units play in contemporary conflicts, particularly in operations conducted in urban environments. Their ability to influence the course of operations through the construction of various types of obstacles, the fortification of structures, the emplacement of defensive and siege barriers, the overcoming of different types of obstacles, clearance operations, repair and construction of temporary lines of communication, the application of camouflage discipline measures, as well as the destruction of infrastructure, affected both military actions and the lives of the civilian population.

Forces organizing the defense in a populated area confirmed the necessity of employing engineering units on specialized tasks that require technical means and expertise. Their engagement was directed toward the emplacement of mine–explosive obstacles (minefields, groups of mines, booby traps), the construction of obstacles created by demolition, the digging of trenches and lines of communication, and the construction of anti-tank barriers. It is important to note that through the construction of fortification structures and the adaptation of underground facilities and corridors for the accommodation and movement of personnel (the use of underground tunnels at the Azovstal plant), Ukrainian forces were provided with conditions to withstand the siege for a longer period, enabling them to conserve resources and provide protection to civilians.

At the same time, engineering units of the Russian forces employed their capabilities to overcome various obstacles (mine–explosive and demolition-created), clear rubble, repair damaged and construct new lines of communication, and emplace various types of obstacles that further isolated the city.

Common to both sides, based on incurred losses, is the fact that the application of camouflage discipline proved to be essential. A large number of reports present aerial footage showing the consequences of failing to apply camouflage discipline measures, which resulted in the loss of personnel and materiel. In the later phases of the conflict, various photographs reveal the implementation of camouflage measures that significantly extended survivability on the battlefield. On this basis, it can be concluded that the application of camouflage discipline measures is necessary even prior to the commencement of works (in order to prevent the monitoring of the location where work is being carried out, the type of work, and the size of the structure being constructed).

Nevertheless, despite these military advantages, the role of engineering units in Mariupol also illustrated the negative aspects of engineering activities. This situation clearly demonstrated that the tasks performed by engineering units, as a significant branch of the armed forces, may have long-term consequences for the civilian population in conditions of urban conflict. It is necessary to emphasize that the consequences of the emplacement of mine–explosive obstacles and other explosive remnants of war on the territory of Ukraine cannot be remedied within the next 750 years (GICHD, 2024; Novik, P., 2023). Such an approach raises the question of the expediency of the measures undertaken to achieve an immediate objective and the justification of exposing any side to the costs of humanitarian demining, which will last for an indeterminate number of years.

By examining examples of the employment of engineering units, the changes arising from the application of modern combat systems, the necessity of training personnel to operate under newly emerging conditions, the obligation to monitor innovations in the use of various weapons, equipment, and devices, as well as the need for continuous analysis of positive and negative experiences, members of the Serbian Armed Forces are faced with the obligation of constant reassessment regarding the next steps and the direction of future development.

For members of the engineering branch, there is a clear need for continuous improvement of readiness to execute specialized tasks, enhancement of existing knowledge and the implementation of identified lessons learned, monitoring the level of innovation in the field of technological advancements, and considering innovations in engineering mechanization that would improve the effectiveness of engineering works (during defensive operations) and enable the maintenance of the tempo of combat unit advances (through equipping with armored combat engineering vehicles). This also includes consideration of introducing new assets and systems—such as drones—into operational use for timely situational awareness on the battlefield and for monitoring the execution of camouflage measures, all with the aim of improving the capabilities of national forces to conduct combat operations and to enhance their endurance and survivability on the battlefield. An important component that must not be neglected relates to the development of capacities for humanitarian demining as a form of support to the civilian sector after the cessation of hostilities.

Further research on the employment of engineering units should be directed toward changes in the tactics of engineering unit employment, which will be conditioned by modifications in unit organization, the definition of new tasks imposed by the introduction of new assets, as well as the consideration of possibilities for forming certain temporary task organizations in accordance with the dimensions of the combat environment.

Finally, the role of engineering units in the siege of Mariupol is not only an illustration of their vital military function but also an important lesson regarding responsibility for the protection of civilians. Contemporary military conflicts require a comprehensive approach that balances the tactical advantages of engineering with the need to preserve human lives and reduce civilian casualties.

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S u m m a r y

The Battle for Mariupol was one of the most intense and significant engagements in the Russo-Ukrainian armed conflict to date, demonstrating the importance of the role played by engineering units in contemporary warfare, particularly in operations conducted in urban environments. Their purpose and capability—through the construction of various types of obstacles, fortification of structures, emplacement of defensive and siege barriers, overcoming different types of obstacles, clearance operations, repair and construction of temporary lines of communication, application of camouflage discipline measures, as well as the destruction of infrastructure—had an impact not only on the course and outcome of military operations but also on the lives of the civilian population.

Forces organizing the defense in a populated area confirmed the necessity of employing engineering units on specialized tasks requiring technical means and expertise. Through the construction of fortification structures and the adaptation of underground facilities and corridors for the accommodation and movement of personnel (notably the use of underground tunnels at the Azovstal plant), Ukrainian forces were provided with conditions to withstand the siege for a longer period, enabling them to conserve resources and offer protection to civilians. In order to prevent the advance of Russian units, various types of obstacles were constructed—primarily mine–explosive

obstacles and those created by demolition—regardless of the consequences for the local population.

At the same time, engineering units of the Russian forces were required to employ their capabilities to overcome various obstacles (mine–explosive and demolition-created), clear rubble, repair damaged infrastructure, construct new lines of communication, and emplace different types of obstacles that further isolated the city.

Despite the large number of successfully executed tasks, the role of engineering units in Mariupol also illustrated the negative aspects of engineering activities. The tasks performed by engineering units, as a significant branch of the armed forces, leave long-term consequences for the civilian population in conditions of urban conflict. An enormous quantity of mine–explosive obstacles and other explosive remnants of the special operation has been emplaced on the territory of Ukraine. According to official data from the Geneva International Centre for Humanitarian Demining, it will not be possible to remediate the territory of Ukraine within the next 750 years (GICHD, 2024; Novik, 2023). These consequences raise the question of the expediency of the measures undertaken to achieve immediate objectives and the justification of exposing any side to the costs of humanitarian demining, which will last for an indeterminate number of years.

Through a comprehensive analysis of examples of engineering unit employment and the changes that have emerged, members of the Serbian Armed Forces are confronted with the obligation of constant reassessment regarding future steps and directions of development. For members of the engineering branch, there is a clear need for continuous improvement of readiness to execute specialized tasks, enhancement of existing knowledge and implementation of identified lessons learned, monitoring innovations in the field of technological advancement, and considering innovations in engineering mechanization that would improve the effectiveness of engineering works in defensive operations and enable the maintenance of the tempo of combat unit advances (including equipping with armored combat engineering vehicles). This also includes consideration of introducing new systems into operational use, such as drones, in order to ensure timely situational awareness on the battlefield and control of executed camouflage measures—all with the aim of improving the capabilities of national forces to conduct combat operations and to enhance their endurance and survivability on the battlefield. An important component that must not be neglected relates to the development of capacities for humanitarian demining as a form of support to the civilian sector after the cessation of hostilities.

Ultimately, the role of engineering units in the siege of Mariupol is not only an illustration of their vital military function but also an important lesson in responsibility for the protection of civilians. Contemporary military conflicts require a comprehensive approach that balances the tactical advantages of engineering with the need to preserve human life and reduce civilian casualties.