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THEORETICAL FRAMEWORK AND APPLIED ENGINEERING STRATEGIES FOR THE FINAL DEVELOPMENT STAGE OF AZERBAIJAN'S OFFSHORE OIL AND GAS FIELDS

Specialty: 2526.01 - "Technologies for the development of offshore mineral resources"

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THESIS ABSTRACT

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GENERAL DESCRIPTION OF WORK

Urgency of the research topic and the degree of development. The sustainable advancement of the oil and gas industry necessitates the stable and efficient extraction of hydrocarbons. In this context, the development and implementation of robust offshore oil and gas infrastructure—particularly the construction of durable hydraulic engineering facilities and the maintenance of the long-term operational reliability of existing platforms and trestles—are of critical importance. Ensuring consistent and enhanced hydrocarbon output remains an ever-relevant challenge.

Accordingly, this dissertation addresses several pivotal aspects of field development and operational efficiency. These include the optimization of rod-type deep-well pumping systems, strategies to enhance oil recovery in water-invaded reservoirs, improvement of isolation techniques to prevent water ingress in wells, and measures aimed at increasing the operational efficiency of wells affected by sand production and paraffin deposition. Furthermore, the research investigates advanced corrosion protection solutions for equipment used in both production and injection wells.

Given the intensifying pace of hydrocarbon extraction, there is a pressing demand to improve the technical and technological workflows across all stages of production. Within this framework, the adoption and deployment of advanced and cost-effective technologies are deemed essential for maintaining production stability and enhancing operational outcomes. The study also considers the necessity of upgrading offshore hydraulic structures, optimizing crude oil processing facilities, and implementing targeted interventions to mitigate reservoir flooding, water breakthrough, sand accumulation, and paraffin buildup.

This dissertation offers a comprehensive analysis of the aforementioned challenges, explores strategic pathways for their resolution, proposes innovative engineering and technological solutions, and documents their practical implementation within field operations.

Object and subject matter of research.

The primary objective of this dissertation is to develop the scientific foundations of a decision-making system aimed at enhancing the reliability of offshore hydraulic structures, improving well performance, addressing environmental challenges, and increasing operational efficiency during the extraction of residual reserves in offshore oil and gas fields.

Methods for solving the tasks set

The research was conducted using a combination of mathematical modeling, advanced computational tools, experimental analysis, and field-based mining investigations.

Provisions for defense:

The dissertation defends the following scientific and practical provisions aimed at advancing the final stage of development in offshore oil and gas fields:

1. Innovative Technologies for the Construction, Repair, and Reconstruction of Hydraulic Structures:

- A technology for replacing corroded metal beams with reinforced concrete beams in metal-frame hydraulic structures to enhance durability and structural integrity;
- A novel pier construction method utilizing spatial beams of a new design with extended spans (12 meters) for improved load-bearing performance;
- A floating drilling rig design enabling both drilling and decommissioning operations for offshore oil and gas wells;
- The "steel jacket" (or “steel shirt”) technology for structural reinforcement and restoration of corroded metal-pipe support piles.

2. Advanced Devices and Methods for Field Development:

- A newly developed separator device for the effective phase separation of gas, oil, water, and mechanical impurities;
- A sand-sedimenting apparatus designed to prevent the accumulation of sand in surface transportation pipelines;
- A computational methodology for determining the stress–strain state of storage tanks constructed from nonlinearly elastic materials.

3. Novel Technologies for the Recovery of Residual Hydrocarbon Reserves:

- An enhanced rod-type deep well pump unit engineered to minimize fluid leakage and improve operational efficiency;
- A hydrophobic tamponade composition developed for high-efficiency isolation of water intrusion in production wells;
- A corrosion protection method for tubing columns in production and injection wells using high-voltage magnetic field exposure.

Scientific novelty of the research:

Significant scientific advancements have been achieved to enhance the efficiency of oil and gas extraction processes:

1. Development of novel construction, repair, and reconstruction technologies for hydraulic structures:

- A technology for replacing metal beams with reinforced concrete beams in metal-framework hydraulic structures to improve durability and service life;
- A construction method utilizing spatial beams with an innovative design, featuring extended spans of 12 meters for pier construction;
- The “steel shirt” technology for rehabilitating and reinforcing metal-pipe support piles;
- A floating drilling rig designed for both drilling operations and the decommissioning of oil and gas wells.

2. Development of new devices and methodologies for field development:

- An advanced device enabling effective separation of gas, oil, water, and mechanical impurities with high qualitative performance;
- A sand-settling apparatus designed to prevent sedimentation of sand particles in surface transport pipelines;
- A computational method for analyzing the stress-strain behavior of storage tanks composed of nonlinear elastic materials.

3. Development of new devices, compositions, and techniques for the exploitation of residual hydrocarbon reserves:

- A rod-type deep well pump unit engineered to minimize fluid leakage and improve operational efficiency;
- A hydrophobic tamponade composition formulated to isolate and control water influx within wells.

Theoretical and practical significance of the research.

The results of the research conducted in the dissertation can be successfully used in solving many theoretical problems. Thus, it has been proven that the theoretical results obtained in the dissertation can be used in the calculation and design work for the development of hydraulic structures, equipment and transmission lines for the development of fields during the development of residual reserves of offshore oil and gas fields in the final stage of development, as well as for the creation of methods, devices, compositions for increasing production and for the protection of equipment from corrosion.

The applied outcomes of the dissertation work are demonstrated through the following practical implementations:

- The use of corrosion-resistant and cost-effective materials in major repair and reconstruction projects has been systematically analyzed with respect to extending the service life of hydraulic structures. Key evaluation criteria included facility longevity post-repair, economic efficiency, minimization of downtime, and energy consumption. Based on these factors, a novel repair methodology was developed. This method targets the long-term operation of piers with supporting structures experiencing corrosion levels up to 30%. It involves the creation of a monolithic supporting structure within the submerged parts of piers and pier-side platforms situated in sea depths ranging from 5 to 14 meters. The implementation of this method demonstrated significant effectiveness, including an extension of operational life by at least 25 years post-repair, a reduction in repair costs by approximately 50%, and enhanced structural safety. Facilities repaired using this approach showed an increase in service life from an initial 15 years to 30 years after intervention. This technology was successfully applied in key oil and gas infrastructure projects, such as the "Neft Dashlari

Gas-Turbine Thermal Power Plant 35 kVA Substation" and the "Hydrotechnical Installation Repair of the Port Complex in the New Settlement of Chilov Island," yielding an economic benefit of up to 5 million AZN, representing approximately 50% cost savings.

- In the construction of a new pier featuring a 12-meter span, an innovative technological solution was introduced that involved repositioning the construction crane forward towards the newly suspended cantilever beam. This advancement enabled the construction of longer-span piers with enhanced efficiency. The crane's transfer from the support system axis to the cantilever side was facilitated by installing oblique supports on piles positioned 3 meters from the cantilever and increasing the cantilever beam's height by 60 to 90 centimeters. Consequently, the pile driving depth was reduced from 12 meters to 9 meters, enabling the use of lighter, conventional cranes and eliminating the need for larger, heavier-duty cranes. The construction of the 12-meter span pier was achieved in a timeframe comparable to that of a 10-meter span pier, but with a 20% reduction in construction time and a 25% saving in metal consumption. This new construction method offers substantial economic advantages in the offshore oil and gas sector, translating to savings of approximately 1.5 million AZN for the completed section, with total expected savings reaching 8 million AZN upon full completion.

- For the first time, the restoration of 329 support piles at the Compressor Station platform in the Guneshli field was successfully carried out using steel jackets applied from the base to the top, thereby restoring their original strength characteristics. This achievement addressed the critical need to extend the operational lifespan of the facility, a task demanding high technical expertise in assessing work feasibility and accurately evaluating risk levels. The implementation of this structural restoration facilitated the safe continuation of operations at Compressor Station No. 2 for an additional period, yielding an economic benefit of approximately 200 million AZN.

- Theoretical studies and structural calculations developed specifically for the restoration and adaptation of this platform to the new water conditions of the Guneshli field were effectively translated into practice. After the support block was submerged in the 170-meter-deep waters of the Caspian Sea, it was precisely positioned using specialized vessels and secured by driving in support piles. The subsequent elevation of the support block was successfully achieved using a “synchronized multiple hydraulic jack,” which contributed to an economic benefit estimated at 17 million AZN.

In the area of fluid mixture separation, a novel OGWS (oil-gas-water-sand) separating unit was proposed, comprising two vertically interconnected cylindrical bodies equipped with tailored inlet and outlet nozzles, as well as control and measurement instruments. This design enabled efficient separation of gas, oil, water, and mechanical impurities within each cylindrical chamber. Based on the findings of the dissertation, the deployment of the OGWS separator at the “New Oil Collection Point” of the Absheronneft Oil and Gas Production Department (OGPD) effectively addressed environmental concerns and minimized oil losses, resulting in an economic benefit of 23 million AZN.

A total of seven patents have been secured for the methods, devices, and compositions developed within this research, including four Eurasian patents and three patents registered in the Republic of Azerbaijan:

- Method for capturing mechanical mixtures in the flow of formation fluids, Eurasian Patent (EA №033309);
- Method for isolating water flows in wells, Eurasian Patent (EA №034715);
- Method for developing liquefied formation, Eurasian Patent (EA №034719);
- Method for preventing sand plug formation in wells, Eurasian Patent (EA №036356);
- Hydrophobic composition for oil and gas wells, Patent of the Republic of Azerbaijan (И20190091);
- Combined well pumping unit, Patent of the Republic of Azerbaijan (И20190093);

- Separator for oil-gas-water-sand mixtures, Patent of the Republic of Azerbaijan (И20160076).

Approbation and application of work.

The main points of the completed dissertation work were explained in reports at various conferences:

- Bulatov Readings, Proceedings of the V International Scientific and Practical Conference (March 31, 2021) pp. 138-140;
- Proceedings of the International Scientific and Practical Conference "Modern Problems of Construction" dedicated to the 100th anniversary of the Azerbaijan University of Architecture and Construction, Baku, December 18–19, 2020, pp. 182–187;
- Proceedings of the All-Ukrainian Scientific and Technical Conference with the 3rd International Participation "Today's Technological Design, Operation and Repair of Ships, Marine Technical Equipment and Engineering Equipment," May 23–24, 2019, Mykolaiv, Ukraine, Admiral Makarov National University of Shipbuilding.
- Proceedings of the X International Scientific and Technical Conference "Innovations in Shipbuilding and Ocean Engineering," Volume I, April 26–28, 2019, Mykolaiv, Ukraine, Admiral Makarov National University of Shipbuilding.
- Collection of Papers of the International Scientific and Practical Conference "Modern Methods of Developing Fields with Hard-to-Recover Reserves and Unconventional Reservoirs," Volume 2, Atyrau, September 5–6, 2019, pp. 128–131.
- Proceedings of the Conference on "Actual Problems of Offshore Oil and Gas Field Development," dedicated to the 100th Anniversary of the Birth of Israfil Guliyev. Baku: Azerbaijan State Oil and Industry University, March 1, 2017.
- Proceedings of the XX International Scientific and Practical Conference "Fundamental and Applied Research in the Modern World," Volume 1, St. Petersburg, December 4, 2017, pp. 47–52.
- Proceedings of the XII International Scientific and Practical Oil and Gas Conference, Kislovodsk, September 28 – October 2, 2015, pp. 74–75.

Published papers.

A total of 39 scientific works has been published based on the dissertation, including 23 peer-reviewed scientific articles, 9 conference proceedings, 3 patents of the Republic of Azerbaijan, and 4 Eurasian patents.

The name of the institution where the dissertation work was performed

Dissertation work was performed at SOCAR, "OilGasScientificResearchProject" Institute.

The total volume of the dissertation in characters, indicating the volume of the structural sections of the dissertation separately. The dissertation work consists of: introduction, 4 chapters, conclusions, a list of used literature in 141 titles and 5 appendices. The total volume of the work is 301 pages, including 94 figures, 37 tables, a list of literature and appendices. The volume of the dissertation work: introduction 58304 characters, chapter I 126698 characters, chapter II 63060 characters, chapter III 58578 characters, chapter IV 60706 characters, conclusion and proposals 3561 characters, a total of 370907 characters.

Contribution of the author.

The author was directly involved in the planning and execution of the scientific research presented in the dissertation, including problem formulation, selection of research methodologies, and development of computational models. He contributed significantly to the creation of novel construction, repair, and reconstruction technologies for hydraulic structures, as well as the development of new methods and devices aimed at enhancing field performance. Furthermore, the author played a leading role in devising methods and compositions to increase oil recovery during the final stages of reservoir development. He also supervised the selection and justification of all topics covered in the published scientific articles and reports related to the dissertation, formulated the research methodology, prepared comprehensive literature reviews, and facilitated the application and evaluation of the developed devices and methods within the oil and gas production units of the AzNEFT Production Union.

Simultaneously, the author served as the principal investigator and responsible executor of the scientific research, design, exploratory, and implementation works conducted at the SOCAR "Oilgasscientificresearchproject" Institute, which constituted the core content of this dissertation.

SHORT SUMMARY OF WORK

The introduction outlines the main provisions of the completed dissertation, substantiates the relevance of the research, highlights the scientific innovations achieved, presents the key theses proposed for defense, and describes the methods and approaches used to address the research problems.

Chapter 1 is dedicated to addressing key challenges by analyzing the historical development and operational phases of hydraulic structures—such as pile-type platforms, piers, pier-like platforms, and both shallow- and deep-water offshore platforms—which play a critical role in the exploitation of offshore oil and gas fields. The chapter emphasizes that the repair of existing structures and the construction of new ones are pressing issues in offshore field development. This urgency stems from the fact that the service life of current hydraulic structures is significantly shorter than the life span of the fields they support. Therefore, reducing the time between major repairs, extending the service life of newly built structures beyond that of traditional designs, minimizing material and labor costs during construction and repair, and shortening project timelines are presented as key efficiency factors for the successful development and depletion of offshore reserves. The chapter highlights the relevance of these challenges and reflects on various solutions pursued in this direction.

Furthermore, the chapter explores a range of methods aimed at increasing the reliability and longevity of offshore oil and gas hydraulic structures. It focuses on the development of more durable, dependable, and economically viable facilities that can ensure the sustainable exploitation of oil, gas, and gas condensate fields. It also addresses the necessity of maintaining the strength and operational capability of existing platforms and piers through timely repairs, reinforcement, reconstruction, or full replacement. The study approaches these facilities as complex dynamic systems, investigating ways to restore their original load-bearing capacity and resolve associated technical challenges.

The research places particular emphasis on ensuring the long-term structural integrity of piers, foundations, and underwater pipelines. It classifies piers into four zones based on corrosion intensity: (1) the marine atmospheric zone, (2) the splash or tidal zone—exposed alternately to air and seawater, (3) the fully submerged zone, and (4) the underground embedded zone. The study advocates for the use of corrosion-resistant, alloyed steel types and the application of technologies with high technical and economic performance. Special attention is given to the repair of pier structures that have partially or completely lost their load-bearing capacity due to corrosion, and to the combined use of monolithic and prefabricated reinforced concrete elements alongside steel structures. Techniques such as covering structural elements with composite materials to increase their strength, and implementing more robust corrosion protection strategies—especially in the highly corrosive splash zone—are proposed to enhance the durability, efficiency, and reliability of offshore hydraulic systems.

In order to ensure the long-term operation of metal piers and pier-type platforms, the possibility of using reinforced concrete, monolithic reinforced concrete, and composite concrete structures in support elements has been considered. The technology of increasing their durability, mechanical strength, rigidity, and corrosion resistance by covering the outer surfaces of trusses, crossbars, and supports with composite materials has been put forward. In addition to steel structural elements, the use of profiles, channels, angles, twin-section members, pipes, and fittings made entirely of composite materials has also been proposed. Along with prefabricated reinforced concrete pier structures, the widespread application of monolithic reinforced concrete constructions in the development of modern pier-type platforms is considered appropriate.

Taking into account the high corrosion rate in the supporting piles of pier and pier-type platform structures—particularly in the periodic wetting zone—it is observed that after 18–20 years, up to 30% (or more, depending on the aggressive electrolyte environment) of the piles deteriorate and collapse. This creates the need to restore critical structures by replacing the worn elements to maintain the operational functionality of these piers and platforms. According to the newly developed technology, the supporting piles of the pier structures are reinforced using monolithic reinforced concrete (pipe-concrete)

systems, thereby ensuring the initial stability and strength of the structure and restoring its original load-bearing capacity. This creates a foundation for the extended operation of the support system for an additional 20 years.
Several variants of reinforced concrete support structures for piers and pier-type platforms have been developed, and the physical and mechanical properties of the soil and load-bearing capacity have been determined. The implementation of this work demonstrated that by installing a monolithic reinforced concrete system in the support zone of piers exposed to periodic wetting, the service life of the structure can be extended by another 20 years, repair costs can be reduced, the construction period can be shortened by half, and labour intensity can also be significantly decreased.
On the other hand, the dissertation recommends the installation of support elements and decks using composite monolithic reinforced concrete structures to ensure the long-term and reliable operation of newly constructed, repaired, and reconstructed piers and pier-type platforms, which play a vital role in the development of offshore oil and gas fields, particularly in shallow-water environments.
To increase the service life of existing and new hydrotechnical facilities—constructed from metal structures onshore in the form of spatial frames with various geometric configurations, and serving as critical support systems for offshore oil and gas extraction, initial separation, and transportation complexes—a comprehensive installation methodology has been proposed. This includes transporting support blocks by barge to the designated coordinate point, followed by ballast-based differential control and lowering from the barge, rotation and precise positioning using tugboats, and final seabed installation using ballast systems. After full placement on the seabed, the process continues with the driving of initial piles, cutting of side pontoons, and structural enhancements such as increasing the span distance of newly constructed piers to optimise material usage, reduce construction time, and lower labour requirements.
The dissertation also explores the feasibility of using existing equipment and mechanisms to install perforated wall span space

beams and proposes a new method for their offshore installation. It further includes a detailed study of the hydrometeorological conditions of oil and gas production areas in the Azerbaijani sector of the Caspian Sea—covering parameters such as air and water temperatures, wind speeds, wave heights, current velocities, and the recurrence of specific environmental conditions. Based on long-term data from hydrometeorological observation stations, the research emphasises accurate incorporation of these parameters into structural calculation models depending on the timing, nature, and type of marine operations.

Finally, the work investigates the impact of these hydrometeorological parameters on the performance of hydrotechnical structures, applying them in various design scenarios, particularly for stationary hydrotechnical structures and self-propelled floating facilities. These facilities are critical to the offshore development process, and accurate modeling of wave and wind loads is essential for their reliable operation and safety.

Since the economic efficiency of both new construction and major renovation projects of pier platforms is a priority for stakeholders, continuous research has been conducted in this area. According to these studies, two key factors must be emphasized to further enhance economic efficiency, particularly in the design of pier platforms:

- Minimizing the number of support piles while optimizing their geometric parameters to meet the required service life;
- Reducing the overall weight of the pier platform structures and increasing their span length by using lighter structural elements.

Based on these criteria, new 12-meter span beams have been designed and implemented in pier platform construction, achieving up to 25% material savings in metal consumption alone. Traditionally, 10-meter space beam structures made of 60 No. 2 steel have been used with a maximum span of 10 meters. Extending the span by at least 2 meters would typically require increasing the beam height to 90 cm under standard load conditions. However, this approach leads to significantly higher metal consumption due to the use of large-height rolled double girders.

The dissertation demonstrates that the novel span beam design developed during this work reduces metal consumption without significantly increasing the beam's weight. This was achieved by reinforcing the perforated walls of conventional rolled double girders with tubular stiffening elements.
Furthermore, the study reveals that modern parallel flange and wide-flange rolled double girders with wall heights up to 1 meter can be effectively used for spans ranging from 13 to 15 meters, even under heavy load conditions. The labor intensity for manufacturing beam-based span structures is 2 to 2.5 times lower than that required for fabricating trusses of the same span. However, metal consumption for beams of equivalent span is on average 1.5 times greater than that of trusses, while beam height is approximately 2.5 times less. Although reducing structural height is advantageous, it necessitates an increase in the cross-sectional area of the flanges. Additionally, the wall thickness of rolled double-section beams is generally substantial, ranging between 1/50 and 1/65 of their height.
To completely eliminate hazardous situations during the design of pier platform beams, a novel approach was introduced for the first time: both flanges of the beam were interconnected using tubular elements positioned at the midpoints of the perforated sections of the beam walls. This innovation effectively addressed issues related to local stability, critical stress concentrations at hole corners, and beam deflection. Additionally, this design facilitates the assembly of space-frame pier platform beams at sea using existing technical equipment, without the need for additional machinery or mechanisms during construction.
The dissertation also proposes a more efficient and effective new technology for pier restoration. While prefabricated reinforced concrete pier structures are widely used in modern pier platform construction, monolithic reinforced concrete structures have become increasingly prevalent. Studies indicate that in the Caspian Sea region, 30-40% of load-bearing metal structural elements severely affected by corrosion are replaced during major repairs. Given the corrosion rate in the periodic wetting zone of piers—approximately 0.3-0.4 mm/year—it is estimated that up to 30% of piers will deteriorate and

require replacement after 18-20 years of service.

According to the newly developed technology, pier support elements are reinforced using monolithic reinforced concrete (pipe-concrete) structures, which restore the initial stability of the structure and extend the operational life of the support system by an additional 20 years. The restoration method involves dismantling the reinforced concrete pans on the farm near the pier support pillars, machining the relevant sections of the pier pillar to accommodate a seat that holds the replacement shaft supporting the crossbar, and installing this seat. Subsequently, the remaining portion of the shaft inside the pillar is cut out and removed, preparing the pillar for the reinforcement work.

The soil inside the pier pillar is removed appropriately, and monolithic concrete casting is performed up to 1 meter from the top of the prepared pier. The metal girder is reinforced in this process, utilizing the existing corroded metal girder as a formwork. After monolithic casting of the supporting elements—girders and pillars—a single integrated monolithic reinforced concrete support system is created, which can fully replace the existing metal structures in terms of load-bearing capacity and stability.

On the other hand, supporting structures of piers constructed entirely from reinforced concrete are also vulnerable to degradation caused by the aggressive marine environment. To address this issue, a technology has been developed to insulate the sections of reinforced concrete structures located within the periodic wetting zone using composite materials. Preliminary studies indicate that the application of composite materials can significantly enhance the mechanical strength of reinforced concrete structures. Notably, the reinforcement yarns selected for this purpose differ from conventional glass yarns typically used as fillers in composites, due to their superior physical and chemical properties.

At water depths of 1–3 meters, connections between the pillars are installed, and special arched covers—fabricated by cutting large-diameter pipes—are welded into place. According to the proposed method, the pier platform structures of the pier, the reinforced concrete decks in pedestrian areas, and other metal components are either strengthened or replaced depending on their technical condition. The use of reinforced concrete elements in the supporting structures enables a significant increase in the service life of piers.

The table below compares the metal consumption required for the primary structural components in pier construction between the dissertation-proposed method and the traditional approach (Table 1).

Table 1

Comparison of Metal Consumption for Structural Components between the Proposed Method and the Traditional Method in the Dissertation

Indicators	Consumption of basic construction materials	
	Current method	Suggested method
Metal (tons)	137	26,5
— Ø426x11 mm pier pillar	92,9	-
— Rigel, two-stage 60Б1	17,6	-
— Tier-type truss, two-stage 60Б1	26,5	26,5
Reinforced concrete (m^3)		
— Precast (B-25)	86	86
— Monolithic (B-25)	16	90
— Monolithic (B-30)	-	20
Reinforcement (tons)	15,5	32
Construction period (including preparation), months	4	5

Summary of Key Findings and Methodology Material Efficiency and Cost Savings: The proposed pier structure method reduces metal consumption by 110.5 tons compared to traditional metal pier structures. For a 100 linear meter combined structure pier at 14 meters depth, construction materials cost approximately half of that for an equivalent metal structure pier. Dynamic Interaction and

Soil Modeling. The interaction between marine hydraulic installations and shelf soils through pile foundations is studied as a complex dynamic system incorporating wave sources and soil properties. A combined rheological model of shelf soil using Kelvin and Maxwell body models was employed to analyze wave shock transmission, including longitudinal, transverse, and surface wave propagation in an elastic half-space system. Hydrometeorological Conditions in the Caspian Sea. The extensive north-south spread (~1200 km) of the Caspian Sea results in considerable spatial and temporal variability of hydrometeorological parameters such as temperature, wind, waves, atmospheric circulation, seabed relief, and water mixing. Detailed analysis was conducted specifically on the "Gunashli" field water area. Stability and Safety of Offshore Hydraulic Devices:

Reports were prepared analyzing skid safety factors, overturning resistance, footing depth immersion, and minimum freeboard safety for floating drilling devices. The high center of gravity and wave-induced motion in deep water create stability challenges, making precise buoyancy and stability calculations critical. Structural Load Analysis using STAAD.Pro, the vertical, horizontal, and combined load values on each support leg under specific conditions were computed. These values, along with sliding safety factors, are detailed in Table 2.

Table 2

Loads acting on supports and safety factors in shear

Supports	1	2	3	4
Vertical forces, tq	674,74	690,9	1310,8	1292,9
Horizontal forces, tq	98,70	103,7	96,69	100,9
Safety factors in sliding $K_{(сд)i}$	2,05	1,99	4,07	3,85
$K_{сд}$	3,67			

Hydrotechnical facilities undergoing major repairs are mainly those in the final stage of operation. There is a high probability of malfunctions and accidents occurring in these facilities. Quantitative risk assessment and determination of the residual risk size are of great importance for the continued safe operation of these facilities. As a result of the research, it was determined that a large part of the hydrotechnical facilities existing at the enterprises of the Azneft PU, including pier platforms (PP), are in the final stage of operation. Further improvement of the existing infrastructure and ensuring occupational safety in these facilities should always be the focus of attention. The major repairs carried out serve to continue the safe operation of hydraulic structures, as well as pier platforms (PP), to reduce the risk of accidents, to maintain a stable production level, and despite the fact that the hydraulic structures are in the final stage of operation, it has been confirmed that these structures can serve up to 40% more than the norm, and in this regard, the determination of their residual resource is of great importance, and since the continuous operation of structures in the oil and gas industry is characterized by the possibility of certain malfunctions and accident risks, it is important to determine the residual risk and take it into account in the operation processes in terms of reducing the risk due to the increase in the probability of accidents at the final stage of operation, taking preventive measures and reducing the danger of accidents in order to ensure continuous and safe operation. The generalized values of multi-year measurements of the rate and intensity of corrosion in support piles made of metal pipes by zones during 22 years of operation in marine conditions are given (Figure 1).

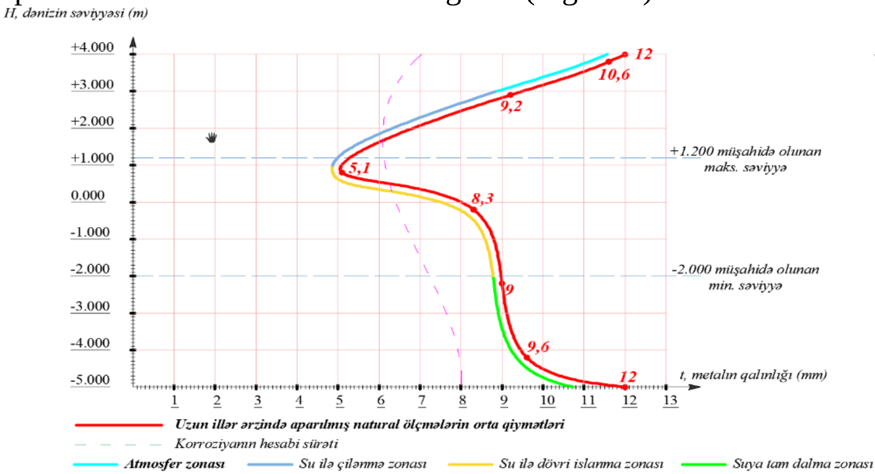

Figure 1. Consolidated corrosion rate and intensity by zones in the support pile

In the development of oil and gas fields in the Azerbaijani sector of the Caspian Sea, the current condition of operational hydraulic structures was investigated and compared with their theoretical service life. Through probabilistic modeling, the residual operational lifespan and associated risks of these structures were determined, demonstrating that they could remain functional beyond their originally intended design life.

To ensure the uninterrupted operation of the gas compressor station at the Guneshli field—which collects and transports associated gas from low-pressure oil wells—critical structural supports of Compressor Station No. 2 (SKS-2) were rehabilitated. The platform, having exceeded its service life and suffered extensive corrosion damage, was reinforced using the "Steel Shirt" method, extending its operational viability by an additional 25 years. This case study confirmed that offshore facilities with significant residual value and strategic importance can achieve a second operational lifecycle with minimal investment and downtime. A new repair methodology was developed through this project, applying the "Steel Shirt" technique to emergency structural reinforcement, using the SKS-2 platform at the "Oil Rocks" field as a practical implementation.

With the need to drill new wells in the Guneshli field, the potential reuse of an abandoned support block—whose construction was halted in the early 1990s—was evaluated. Comprehensive technical assessments, including structural integrity analyses using SACS, STAAD.Pro, GT STRUDL, and FASTRUDL software, confirmed that Platform No. 7 could be repurposed as a support block after necessary reinforcements and slipway material upgrades. The restoration process was executed in stages to ensure structural stability. Transporting the rehabilitated support block via barge for offshore installation was a complex engineering challenge, requiring precise load distribution during lifting to maintain equilibrium.

Key engineering interventions included reinforcing eight nodal points per slipway to align with the block’s center of gravity, installing 32 load-bearing support piles (two 1000-mm-diameter piles per node), and employing 16 synchronized hydraulic jacks to elevate the structure by 700 mm for slipway replacement. These measures

ensured the block's structural readiness for redeployment.
The corrosion rate of the support block's metal components—which had remained incomplete in the production area for over two decades—was thoroughly evaluated to confirm its suitability for reuse in the new deepwater Platform No. 7. The study also examined crack formation and propagation in welded joints, as well as the structural resilience of critical nodes under operational stresses. Hydraulic jacks were utilized to lift the entire block, allowing for the replacement of degraded wooden slipway elements essential for barge loading, transport, and seabed installation.
Strengthening efforts prioritized long-term durability, incorporating reinforced support points for jack-assisted lifting and upgraded slipway materials designed to withstand hydrodynamic and mechanical stresses during marine operations. This project established a novel methodology for repurposing abandoned offshore structures, demonstrating how an inactive support block could be restored and adapted for reuse in a new marine environment.
The first chapter of the dissertation synthesizes field observations, experimental studies, computational analyses, and engineering design work to propose methods for enhancing the reliability and longevity of offshore oil and gas hydraulic structures.
A comprehensive assessment was conducted on the corrosion rate of metal elements in the support block that had remained incomplete in the production area for over 20 years, with the goal of repurposing it for the new deepwater Platform No. 7 in the Gunashli field of the Caspian Sea. The study examined the formation and propagation of existing cracks in weld joints, evaluated the resistance of metal structure nodes to disintegration during the development stage, and implemented a complete lifting operation of the support block using hydraulic jacks. This lifting operation enabled the replacement of deteriorated wooden structures necessary for transferring the block onto a barge.
The reinforcement of support points for jacking operations and the replacement of slipway materials were carefully executed, with all reports and modifications accounting for the complete sequence of operations: sliding the block onto the barge, marine transport,

launching into the water, towing to the installation site, and final positioning on the seabed. This process led to the development of an innovative methodology for adapting and rehabilitating support blocks for new marine environments, demonstrated through the successful restoration of a long-abandoned slipway structure.

The first chapter of the dissertation presents research findings from extensive observations, analytical studies, computational analyses, and engineering design work, culminating in practical solutions for enhancing the reliability and longevity of offshore oil and gas hydraulic structures in the Caspian Sea region.

The second chapter examines methods for improving the efficiency of oil and gas gathering, preparation, and transportation systems. Based on a decade of observations and experiments (2007-2017) at central oil gathering points (COGPs) across various oil and gas production divisions (OGPDs), the study revealed two significant operational challenges: environmental pollution during cleaning of open oil traps and storage tanks, and substantial oil losses during these processes.

To address these issues, the dissertation proposed and implemented several innovative solutions. For OGPDs No. 3 and 4 in the Buzovna area of the H.Z. Tagiyev OGPD, a new COGP was constructed featuring two inclined pipe-type oil-gas-water separators (OGWSS) set at a 6-degree angle to the horizontal plane. These separators were specifically designed for the initial separation of well products into their constituent gas, oil, water, and mechanical mixture components, with each separated stream directed to appropriate storage tanks and secondary processing units.

Similarly, a new measuring station was developed and commissioned for the Absheronneft OGPD, incorporating four vertical tube-type OGWS (oil-gas-water-sand) separators. The design employed a two-stage separation system consisting of two vertically arranged cylindrical vessels connected in series, each equipped with specialized inlet and outlet nozzles and comprehensive monitoring instrumentation. To enhance separation quality, the system integrated hydrocyclones and filters for mechanical impurity removal, complemented by sand collection chambers installed beneath the

separation units.
The research also led to several process optimization improvements. For tank management, a sloped drainage system with a 1:30 gradient and central collection pipe was implemented to effectively handle bottom sediments. In water treatment, the process was enhanced by recirculating demulsification water at optimal temperatures of 55-60°C back to the separator inlets, significantly improving emulsion breaking and oil-water separation efficiency.
These comprehensive upgrades have demonstrated measurable benefits across multiple operational parameters, including reduced environmental impact from cleaning operations, decreased hydrocarbon losses, and improved fluid processing quality. The technical specifications, including the 6-degree separator inclination, optimal recirculation temperature range, drainage slope ratio, and vertical separator configuration, were all carefully maintained according to the original research parameters. This systematic approach to facility modernization successfully addresses both immediate operational challenges and long-term sustainability objectives in oilfield processing operations.
The issue of mechanical impurity management in oil preparation and collection systems was thoroughly investigated, with particular relevance to Azerbaijan's oil fields where poorly cemented rock formations result in consistently high levels of mechanical impurities in transported products. These impurities significantly impair operational efficiency throughout the production chain. To address this challenge, the dissertation presents an innovative sand and mechanical impurity capture method implemented directly within the field pipeline infrastructure.

The proposed solution involves strategic placement of sand settling devices at critical junctures - either within individual well lines or at the confluence of multiple well streams - prior to product collection and preparation points. Through comprehensive calculations, the research established optimal placement parameters for these devices, creating a predictive model for their most effective deployment. The design specifications for these settling devices were precisely calculated by analyzing the relationship between solid

particle settling time and fluid transit time through the device, with careful consideration given to daily fluid volumes.
The engineered sand settling device employs a multi-stage separation process: larger particles are captured in the primary chamber, while an integrated slotted wire filter ensures removal of finer particulate matter. This dual-stage approach provides comprehensive mechanical impurity removal directly in the field pipeline network.
The study also examined separation system challenges in oil and gas production, particularly focusing on gas transportation issues. Thermodynamic conditions during gas transit lead to liquid phase separation and mechanical particle accumulation in pipeline low points, causing multiple operational problems: reduced permeability, increased hydraulic resistance, pressure losses, flow irregularities, vibrations, and hydraulic shocks. These conditions accelerate internal corrosion and erosion processes, compromising pipeline integrity and lifespan while elevating accident risks.
To mitigate these issues, the research proposes a novel technological scheme for gas well product separation, featuring:

1. Wellhead installation of oil-gas separators
2. A specialized trapping vessel positioned upstream of separators
3. Weight-based particle separation utilizing kinetic energy principles (illustrated in Figure 2)

Additionally, the dissertation presents an advanced computational method employing finite difference analysis to determine stress-strain states (SSD) in nonlinear elastic material reservoirs subject to internal pressure, accommodating both variable and constant thickness scenarios. This methodological advancement was implemented through a specially developed software suite for cylindrical casing analysis, providing valuable tools for infrastructure durability assessment and design optimization.
To optimize the oil and gas transportation process, a new approach has been developed focusing on production enhancement through pipeline efficiency improvements. The proposed solution addresses hydraulic loss reduction in transportation pipelines by implementing a decentralized processing strategy.

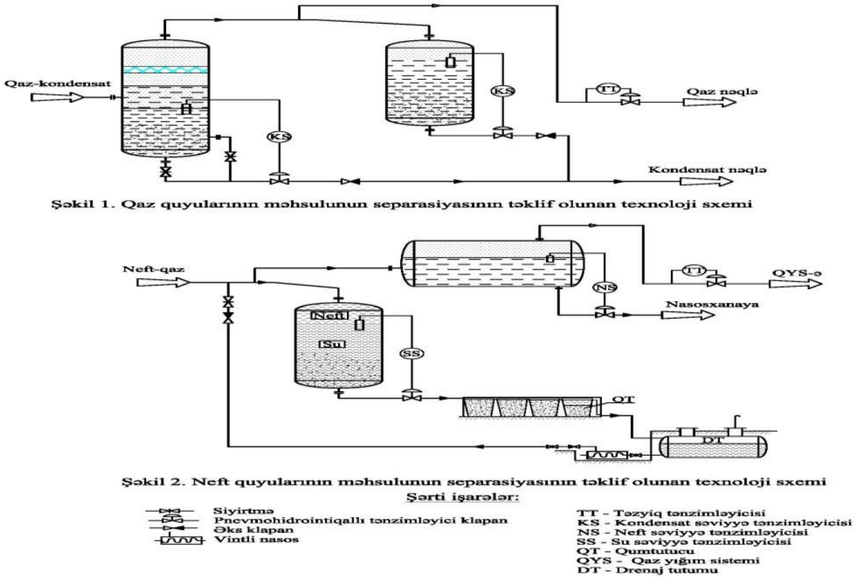

Figure 2. Proposed technological schemes for separation of gas and oil well products

This chapter explores methods to enhance the efficiency of oil collection and preparation systems through the application of specialized equipment and optimized processes. A key development was the design and installation of high-efficiency Oil-Gas-Water-Sand Separators (OGWSS) along with auxiliary equipment, including an advanced sand settling device for mechanical mixture removal. These systems were successfully tested at the inlet of liquid injection pumps on Stationary Deep-Sea Platform No. 4 in the Gunashli field ("28 May" OGPD), demonstrating significant improvements in separation performance.

One of the primary challenges in oil and gas production is ensuring the reliability and efficiency of separation systems. To address this, the study incorporated computational modeling based on the semi-momentum-free theory of coatings, accounting for the physical nonlinearity of materials using the finite difference method. This approach allowed for the optimization of reservoir geometry and an in-depth analysis of the stress-strain state in cylindrical reservoirs with variable cross-sections, particularly under surface loading conditions. Additionally, the research focused on reducing hydraulic losses in oil and gas transportation, leading to more efficient fluid movement.

Beyond separation and transportation improvements, another critical aspect of oilfield development is maximizing production efficiency, which will be discussed in detail in the following chapter. The findings presented here contribute to a more sustainable and cost-effective approach to hydrocarbon extraction, ensuring long-term operational viability in challenging offshore environments.

The third chapter addresses key challenges in enhancing oil production through improved extraction methods, focusing on four main areas: (1) optimizing mechanized production techniques, (2) enhancing reservoir and near-wellbore stimulation methods, (3) mitigating well operation complications, and (4) protecting downhole equipment from corrosion.

A significant innovation involves the redesign of beam pumping systems to eliminate dynamic loads. Conventional units generate variable inertial forces due to the oscillating motion of the polished rod. The proposed solution establishes uniform linear motion in both upward and downward strokes, effectively canceling acceleration-induced inertial forces. This breakthrough provides three key benefits. Elimination of dynamic loads on the rod string. Improved pump filling efficiency. Extended rod service life through reduced stress amplitudes. The implementation combines two pumping technologies:

1. A downhole hydraulic piston pump installed within the production tubing
2. A conventional rod pump suspended below the hydraulic unit
   This configuration substantially reduces rod string length, minimizing elastic deformation and parasitic oscillations that plague conventional systems.

The research also quantifies productivity losses in rod pump systems, identifying two primary mechanisms:

- Progressive wear in the plunger-cylinder interface
- Pressure-induced clearance expansion under fluid column load
  These effects combine to create exponential increases in fluid

slippage over time. A new productivity equation accounting for these losses has been developed, accompanied by three operational improvements:

- Positioning the pump barrel below the anchor packer
- Installing gas-sand separators at pump intakes
- Implementing automated stroke rate control

For reservoir stimulation, the dissertation presents an advanced chemical treatment method for unconsolidated formations. The technique modifies conventional sodium silicate injection by:

1. Pre-mixing carboxylmethylcellulose (CMC) with the silicate solution
2. Precisely adjusting concentration based on:
    - Reservoir temperature at target depth
    - Required gelation time
3. Displacing the treatment with filtered seawater or produced water

This approach provides superior sand control while maintaining formation permeability, addressing the chronic challenge of sand production in weakly consolidated reservoirs. The combined mechanical and chemical solutions presented in this chapter demonstrate measurable improvements in production efficiency and equipment longevity across multiple field applications.

The proposed enhanced oil recovery method involves a carefully designed two-stage injection process. Prior to injecting the sodium silicate solution containing carboxylmethylcellulose (CMC) into the formation, preconditioning is performed through the injection of softened seawater or formation water. This preparatory step ensures optimal reservoir conditions for the subsequent chemical treatment.

The innovative aspect of this technique lies in its ability to precisely control the gel formation process when developing unconsolidated formations. Unlike conventional approaches, this method prevents premature gelation while enabling controlled migration of the chemical solution to establish a gel barrier at predetermined locations within the reservoir. The implementation process begins with comprehensive geological and geophysical studies to identify target isolation intervals and evaluate key reservoir parameters including permeability distribution, formation pressure, bottomhole pressure, and fluid viscosity characteristics.

Using Dupuit's filtration equation, engineers calculate both the required reagent volume and the expected migration distance of the injected solution. This allows for accurate determination of the time needed for the sodium silicate-CMC solution to reach the target depth within the formation. The method's key advantage is its capability to regulate the gel formation process, creating an effective barrier at a specified distance from the injection wellbore. This strategically placed gel screen enables more efficient waterflooding operations by improving reservoir sweep efficiency and increasing oil recovery.

For water control applications, the technique incorporates an isolation method that utilizes organic industrial waste products to selectively block high-permeability zones. This diversion mechanism promotes better fluid distribution and enhances production from previously underutilized low-permeability oil-bearing zones. In the water shutoff procedure, whey is combined with the sodium silicate solution prior to injection, with the concentrations of both components carefully adjusted based on downhole temperature conditions at the target zone and the required gelation time. The specific composition of the whey additive is detailed in Table 3, providing important reference data for treatment design and implementation.

Table3.

The amount of components that make up whey

Components	Amount, q/100 q
Water	93,5
Dry substances Including: lactose proteins milk fat minerals other substances	6,5 4,66 0,91 0,37 0,50 0,06

The addition of whey as a gelation initiator to sodium silicate (Na_2SiO_3) solutions enables precise control over gel formation time within the 40-90°C temperature range. The gelation kinetics depend critically on the concentrations of both sodium silicate and whey, as demonstrated in Table 3.

At low temperatures and minimal whey concentrations, the system remains stable with no observable gelation table 4.

Table 4

Effect of sodium silicate and whey concentration on the emergence period

Na_2SiO_3 thickness, %	whey thickness, %	Gel formation time (in minutes) at the indicated temperatures					
		40^0C	50^0C	60^0C	70^0C	80^0C	90^0C
2	10	-	-	-	662	289	95
	20	-	-	540	308	118	54
	30	-	654	291	156	71	42
	40	516	340	190	97	46	25
	50	45	32	24	15	8	5
4	10	-	-	719	456	242	85
	20	-	840	420	293	100	46
	30	685	511	298	128	60	45
	40	342	286	180	82	38	21
	50	100	70	45	26	8	6
6	10	-	812	502	322	251	77
	20	556	421	373	216	142	52
	30	321	232	209	102	61	38
	40	210	164	122	51	22	19
	50	110	86	39	21	7	4
8	10	-	588	411	278	205	81
	20	412	319	261	184	121	68
	30	285	195	184	92	75	55
	40	180	121	87	72	66	46
	50	90	55	38	19	10	4

As whey concentration increases, the gelation process accelerates significantly lower concentrations result in extended

setting times, while higher concentrations induce rapid gel formation. This controllable behavior allows operators to tailor the treatment based on specific reservoir conditions.
By adjusting the composition concentrations (as detailed in Table 4), the method can be optimized for either complete water flow isolation or partial restriction in the wellbore zone. This flexibility makes it particularly effective for managing water production in diverse reservoir environments.

Development of a Hydrophobic Tamping Composition for Oil and Gas Wells.
A novel hydrophobic tamping composition has been developed to enhance zonal isolation in oil and gas wells. The composition delivers improved mechanical strength and insulation properties while minimizing fluid migration, with accelerated gelation kinetics particularly beneficial for high-water-cut wells.
Composition and Mechanism
The system comprises:

- Primary component: Flexoil CW 288 (depressant-modified hydrophobic agent)
- Solidification accelerator: 5 wt% calcium chloride aqueous solution

Upon mixing, the $CaCl_2$ solution initiates crosslinking in the Flexoil CW 288 matrix, achieving:

- Initial gelation at 20°C within 6–7 hours
- Complete phase transition to solid gel state
- Reduced radial dispersion compared to conventional systems

Laboratory Preparation Protocol

1. Prepare 5% $CaCl_2$ solution (5 g anhydrous $CaCl_2$ in 95 mL DI water)
2. Dissolve Flexoil CW 288 in hydrocarbon carrier fluid under agitation
3. Gradually introduce $CaCl_2$ solution at 20°C with continuous mixing
4. Monitor rheological transition:
   - Liquid → Viscoelastic gel (30–60 min)
   - Gel → Solid (6–7 hr)

Paraffin Control via Production System Optimization
Magnetic Induction Technology (MION Series)

Developed through collaboration between *NPE "LANTAN-1"*, *Center for New Technologies "LANTAN"*, and *Ural State University* (Yekaterinburg, Russia), the system features:

Pipeline Installations (MION-T):

- Magnetic field strength: 1,200 Oe (96 kA/m)
- Compatible with ANSI flanged pipelines (DN 80–200 mm)

Downhole Tools:

- MION-SM 73: Clamp-on tubing deployment
- MION-СШ: Sucker rod integration
- MION-РП: Plunger pump modification
- MION-НЦ: Centrifugal pump retrofit
- Field strength: 3,000 Oe (240 kA/m)

Technical Advantages

- Full-bore designs maintain production hydraulics (ID match to host piping)
- Permanent magnet construction:
  - Neodymium-iron-boron (NdFeB) alloys
  - Samarium-cobalt (SmCo) alloys
- Non-intrusive paraffin inhibition without chemical additives

This integrated approach combines advanced materials science with field-proven engineering solutions to address both near-wellbore isolation and flow assurance challenges in hydrocarbon production systems.

Research on Magnetic Field Effects and Shock Wave Technology in Oilfield Operations.

To conduct the intended research, specialized permanent magnetic laboratory inductors with magnetic field strengths of 40, 120, 200, 280, and 360 kA/m were manufactured by *LANTAN (ЛАНТАН) YTM LLC*. Additionally, a laboratory device simulating the operational conditions of the NKB (presumably a downhole or corrosion-testing apparatus) was developed at the institute.

The study investigated the influence of magnetic fields on the electrochemical corrosion of P-105 steel samples under varying water flow rates through the MION (Magnetic Inductive Treatment Device). Furthermore, the research assessed the chemical and microbiological aggressiveness of both seawater and produced water under magnetic exposure.

Key Findings on Magnetic Treatment of Produced Water

In the "Pereriv formation" water (Well No. 272, DDSP-15), magnetic treatment led to significant changes in water chemistry and microbial activity. The primary observations include:

- Reduction in corrosive agents:
    - Hydrogen sulfide (H_2S) decreased by 25% within 5 hours after magnetic treatment (280 kA/m).
    - Concentrations of Fe^{3+} and Ca^{2+} ions declined.
- Changes in water composition:
    - Bicarbonate ions (HCO_3^-) decreased substantially.
    - Total water hardness and mineralization were reduced.
    - A corresponding shift in pH levels was observed.
- Microbiological impact:
    - Sulfate-reducing bacteria (SRB) populations were significantly suppressed:
        - Adhesive SRB decreased by 55% (from 3×10^{11} to 3×10^5 cells/cm²).
        - Planktonic SRB were reduced by 75–100%.

These effects are attributed to the magnetic deposition (reduction) of sulfates and the inhibition of microbial activity, leading to a less corrosive and more stable water composition.

Development of a Wellhead Shock Wave Device

To enhance formation stimulation, a wellhead device was designed to generate shock waves in the bottomhole zone. The mechanism involves:

- Periodic opening and closing of the gate valve, creating alternating pressure shock waves and pressure drops inside the pump-compressor pipes.
- These waves propagate from the wellhead to the bottomhole and back, effectively stimulating the near-wellbore zone.

This research demonstrates two key advancements in oilfield production optimization:

1. Magnetic water treatment effectively reduces corrosion and microbial activity, improving equipment longevity.
2. Shock wave stimulation enhances formation productivity by dynamically impacting the bottomhole zone.

These innovations contribute to more efficient mechanized oil recovery methods, improving both pumping equipment performance and reservoir stimulation techniques.

Chapter Four: Application of New Technologies and Structural Solutions in Offshore Oil and Gas Production.

Chapter Four presents the implementation of new technologies and structural solutions developed throughout the dissertation, along with challenges encountered in offshore oil and gas production processes.

To ensure the long-term operation of piers affected by up to 30% corrosion (and in some cases even more), a method for major repair and reconstruction was developed. This method involves using the remaining portions of corroded pile structures as formwork for monolithic pier reconstruction in water depths ranging from 5 to 14 metres. It also includes the creation of a complex support frame structure, incorporating double-beam connections between piles.

According to the proposed methodology, the process begins with dismantling the reinforced concrete deck (pans) in the area where the support piles are located. The exposed pile sections are then processed to replace the original shaft (or socket) that held the crossbar with a specially designed seat, which is subsequently installed. The remaining part of the internal shaft is cut out and removed, and the pile is prepared for internal reinforcement.

Next, a reinforcement cage is inserted into the pile and readied for monolithic casting. During the cage design, connection points between piles are predetermined and incorporated into the structure. Once the piles are cast monolithically up to 1 metre above the top level, they are connected using metal crossbars according to the designed reinforcement scheme. Notably, the corroded metal crossbars are reused as formwork.

This repair technique proved effective in extending the service life of the facility, reducing repair costs by approximately 50%, and increasing post-repair durability to a minimum of 25 years—all while maintaining operational safety. The proposed method was applied to strengthen the support piles and beams of the Gas Turbine Thermal Power Plant, covering a total area of 7,000 m² in the *Neft Daşları* (Oil Rocks) region.

However, depending on the corrosion level and operational demands of metal support structures, strengthening beams with monolithic reinforced concrete may be inefficient or time-consuming. Therefore, in most cases, a combined strengthening approach was developed and applied to optimise structural performance and repair time.

During the facility's reconstruction, the entire rigid metal beam system was dismantled and replaced with new prefabricated reinforced concrete beams. Monolithic reinforced concrete anchors were installed within the internal cavities of the support piles, and the connection nodes were strengthened using high-grade concrete through monolithic reinforcement. The reinforcement of the prefabricated beams was selected based on the span length, and specific measures were developed to ensure effective integration of the beams with both the support piles and the floor slabs.

Using the proposed methods, reconstruction and development works for offshore oil and gas infrastructure were successfully executed. Notably, these methods were applied in the major overhaul of the 35 kV substation section of the Gas-Turbine Thermal Power Plant in Oil Rocks and in the repair of hydraulic structures at the port complex in the new settlement on Chilov Island. These projects achieved up to 50% cost efficiency—equivalent to approximately 5 million AZN—compared to traditional construction techniques.

The reinforced concrete structures proposed and applied in the development of offshore oil and gas fields, particularly those severely corroded or at the end of their service life, demonstrated substantial economic benefits when implemented in the operational environments of Oil Rocks OGPD and Chilov Island.

Two key factors contributed significantly to the increased economic efficiency of offshore pier construction:

1. Minimising the Number of Support Piles: Reducing pile count while optimising their geometric parameters according to the required service life.

2. Optimising Pier Structure Design: Implementing lightweight structures and increasing the length of pier spans using space beams. Specifically, 12-metre perforated double-walled beams were introduced as pier components.

The newly designed 12-metre pier beams provided up to 25% savings in metal consumption and were successfully applied in construction. Notably, increasing the pier structure's length by 20% using conventional factory-made double-walled rolled beams would result in a 50% increase in weight under the same operational conditions. In contrast, the newly implemented pier design achieved a 20% increase in length with minimal weight gain—approximately 12% more than traditional structures.

These structural enhancements offered up to 25% economic efficiency in capital and time expenditures when constructing a 100-metre pier using the new system. This innovative pier platform structure was first applied in the Oil Rocks field, in a marine zone with a depth ranging from 9 to 13 metres, at a construction site for a new pier with a total length of 1,950 metres.

The dissertation also introduced a new construction technology for piers using 12-metre perforated pier platform beams. This system utilises two reusable inclined support columns (inventory oblique pillars), allowing the construction of the new pier structure using existing technical and mechanical resources—without requiring additional equipment or machinery beyond those used in traditional pier construction.

Construction and Rehabilitation Technologies in Offshore Oil and Gas Infrastructure.

The construction of a new 12-metre-span pier was achieved with nearly the same operational process as that of a traditional 10-metre pier. However, this new design enabled a 20% reduction in construction time and a 25% decrease in metal consumption, delivering substantial economic benefits. In the oil and gas sector—where efficiency and material optimisation are critical—these gains represent a major advancement. The completed portion of the ongoing pier construction has already resulted in savings of 1.5 million AZN, with an estimated total economic benefit of 8 million

AZN upon full completion.

In addition to innovative pier designs, the dissertation introduces the application of the "Steel Shirt" method—a novel structural rehabilitation approach—for repairing severely deteriorated offshore technological platforms. This method was successfully applied to restore six platforms of Compressor Station No. 2 (SKS-2) in the *Guneshli* field, located in the *Neft Daşları* area. These platforms play a critical role in capturing millions of cubic metres of associated gas that would otherwise be released into the atmosphere. The captured gas is repurposed for gas-lift operations in low-pressure wells and other production needs.

Strategic Importance of Compressor Station No. 2 (SKS-2)

SKS-2 is vital not only for the efficient exploitation of the *Guneshli* field but also for environmental protection and the energy security of the Republic. Maintaining continuous operation of this station has been a top strategic priority. However, as natural reservoir pressures decline, the ability to transport gas to the mainland using its own pressure will soon be compromised. Any operational failure of this station could disrupt the entire oil and gas infrastructure, potentially resulting in a national-level crisis.

The complexity of the challenge was amplified by the following conditions:

- The station consists of 16 interconnected operational units, built into an intricate technological scheme that cannot be interrupted.
- A full replacement of the station was considered unfeasible both economically and logistically, especially given the need to avoid downtime.
- Structural integrity issues had become critical: under strong wind conditions, displacements at connection joints exceeded allowable limits, and layered corrosion in the splash zones of support piles had severely degraded stability.

Implementation and Advantages of the "Steel Shirt" Method

To address these risks, the innovative "Steel Shirt" method was proposed and implemented for the first time. This method involved enclosing and reinforcing 329 corroded support piles from seabed to surface. Key benefits of the method include:

- No requirement for diving labour, large machinery, or complex equipment during the repair process.
- Hermetic sealing of two half-cylinder “steel shirt” sections around each pile, functioning as a single continuous unit.
- Extension of the free length of the jacket structure to 18 metres, with all gaps grouted with concrete to form a monolithic system, mimicking the principles of tubular concrete structures found in structural engineering literature.
- Extended service life of the rehabilitated piles by 25 years, with continued protection through periodic anti-corrosion treatments.
- Load redistribution: the new jacketed structures absorb and transfer part of the axial load from the end beams to the soil, relieving stress on the original pile and shielding it from lateral impacts.
- Wide applicability: the method can be applied to all offshore piles with free lengths over 5 metres, making it a scalable solution for the oil and gas sector.
- Results and Economic Outcomes

The successful restoration of Compressor Station No. 2 using this technique ensured the uninterrupted operation of a critical component of Azerbaijan’s offshore energy infrastructure. In doing so, the project not only extended the operational life of the station but also achieved a remarkable economic benefit of 200 million AZN.

Lifting and Adaptation of Support Block No. 7 Using Synchronized Hydraulic Jacks: A World-First Engineering Achievement.

A unique lifting method was developed and implemented in the BOSHELF area to adapt the support block of Platform No. 7—originally part of the “28 MAY” OGPD “GUNASHLI” field and left idle on the slipway for an extended period—for deployment in a new water area. This method utilized synchronized multiple hydraulic jacks and marked the first such operation of its kind worldwide.

The massive structure, a complex, spring-loaded space frame measuring 151 meters in length and weighing 11,985 tons, was elevated by 700 mm using 16 synchronized hydraulic jacks. To enable this operation, structural modifications were made to adjust the friction parameters between the support block and the slipways.

Restoration and Strengthening Works.

Construction of the support block had been halted in the early 1990s, and significant deterioration was observed due to prolonged exposure. During the completion phase, restoration works included a detailed assessment of cracks in the welded joints, focusing on their potential to compromise structural integrity. Subsequently, the remaining strength reserves of the damaged nodes were evaluated, and extensive strengthening and reconstruction works were performed.

To enable the transfer of Support Block No. 7 onto a barge, existing wooden cushions and Teflon coatings were replaced. The lifting, involving the elevation of a nearly 12,000-ton block, was once again performed using synchronized hydraulic jacks—another world-first.

During the lifting process, the distribution of load and stress across the two lower "belts" of the structure in its standing position was carefully analyzed. Defects resulting from long-term idling were addressed through targeted reinforcement. Reconstruction was performed on key nodes to restore structural integrity fully.

A total of 16 critical lifting points was identified—eight on each sliding path. These points were reinforced appropriately to ensure balanced elevation relative to the block's center of gravity. Reinforcement design measures included protection against local crushing and maintaining weld integrity during lifting.

Design calculations and detailed structural reporting were conducted using modern finite element analysis tools, including STAAD.Pro, SACS, GT STRUDL, and FASTRUDL, ensuring high precision and compliance with structural safety requirements.

Each lifting node was supported by two bored and cast-in-place piles (⌀1000 mm), giving a total of 32 piles. These piles, each with a load-bearing capacity of 500 tons, provided a solid foundation for the hydraulic jacks. Despite significant technical challenges during drilling and casting, specialized machinery was mobilized to complete the work successfully.

Transportation and Installation.

After lifting, the support block was loaded onto a barge at the

BOSHELF area. Transport to the Gunashli field took approximately 48 hours. Upon arrival at the designated coordinates, the structure was successfully lowered into the sea. This innovative, technically justified approach enabled the rehabilitation and deployment of a long-unused structure.

Economic and Practical Outcomes. The synchronized hydraulic jack lifting method enabled a successful and cost-effective restoration, yielding an estimated economic benefit of 17 million AZN.

Furthermore, as proposed in this dissertation, the construction of a new oil collection point was completed at both the Buzovna field of the H.Z. Tagiyev Oil and Gas Production Plant and the Absheronneft Oil and Gas Production Plant, further contributing to infrastructure modernization and operational efficiency. A new Central Oil Gathering Station (COGS) was constructed and commissioned for the "Absheronneft" Oil-Gas Production Department (OGPD), designed on the basis of the central oil gathering point of the H.Z. Tagiyev OGPD. The station includes four vertical tube-type Oil-Gas-Water-Sand Separators (OGWSS) for the initial separation of gas, oil, water, and mechanical impurities from the well product entering the facility. Equipped with control, measurement, and regulation devices, each separator consists of a technological vessel and two vertical cylindrical chambers connected in series. The first chamber is linked to the second via a horizontal pipe in the middle section and an inclined pipe in the lower section. The first chamber features inlet and outlet nozzles for the well product and gas, while the second includes outlet nozzles for gas, oil, produced water, and sedimented mechanical impurities. The separation of gas, oil, water, and mechanical mixtures occurs within each cylindrical chamber of the separator. As a result of the implementation of the "New Oil Collection Point" built at the "Absheronneft" OGPD using the method proposed in the dissertation, environmental issues were resolved, oil losses were eliminated, and an economic benefit of 23 million AZN was achieved. To protect in-field equipment from the abrasive impact of sand, a sand settling device was introduced. The prototype was tested on June 20, 2016, at Platform No. 4 of the "Guneshli" field under the “28 May” OGPD. A key operational issue in this field has been the frequent breakdown of pump components used to transport well fluids. To address this, the sand settling device was installed ahead of the injection pumps on the surface transport lines at Platform No. 4, aiming to shield the pumps from sand-induced wear.

The developed unit comprises two main components: a sand settler and a wire mesh filter designed to mechanically retain sand. The first section of the settling chamber was designed based on the “Borda” and “Coanda” effects, while the second section—the wire mesh filter—was dimensioned according to the principle of filtering sand-laden fluid in a narrow flow channel. The collection and retention of sand and mechanical particles take place within the chambers of the unit. The design parameters of the wire mesh filter were selected based on the principle of trapping sand and mechanical impurities by filtering the slurry through a narrow slit.

Following the unit's commissioning, samples were collected from both the main chamber and the sediment accumulated in the filter for laboratory analysis. The granulometric composition of the sample from the settling chamber is provided in Table 5. The distribution of sand particles by size from the main body of the sand settling device is clearly illustrated in Figure 3. A graphical representation of the granulometric distribution of sand particles collected from the filter section is shown in Figure 4. The corresponding data is presented in Table 6. As shown in the figures, the majority of the sand settles in the chambers located in the main body of the sand settling device.

Table 5

Granulometric composition of a sample taken from the body of a sand settling device

Diameter of particles, 10^{-3} m	Fractional composition, %
>0,425	1,82
0,425– 0,250	16,26
0,250-0,180	26,23
0,180 – 0,106	33,02
0,106 – 0,090	7,51
0,090 – 0,045	11,18
<0,045	3,98

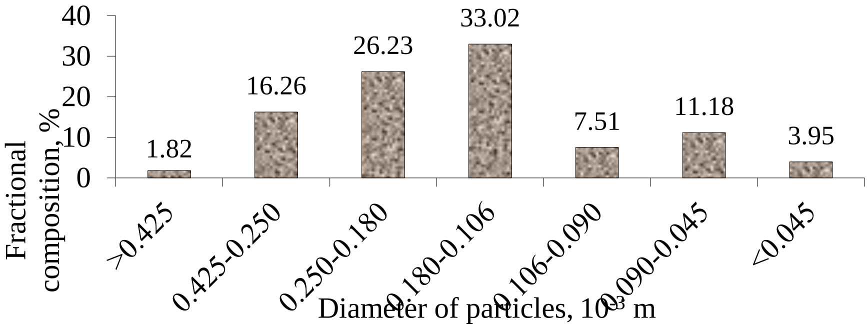

Figure 3. Granulometric composition of a sample taken from the body of a sand settling device

Table 6

Granulometric composition of a sample taken from the filter section of a sand settling device

Diameter of particles, 10^{-3} m	Fractional composition, %
>0,425	1,91
0,425 – 0,250	10,53
0,250 – 0,180	24,23
0,180 – 0,106	35,05
0,106 – 0,090	8,58
0,090 – 0,045	12,58
<0,045	7,12

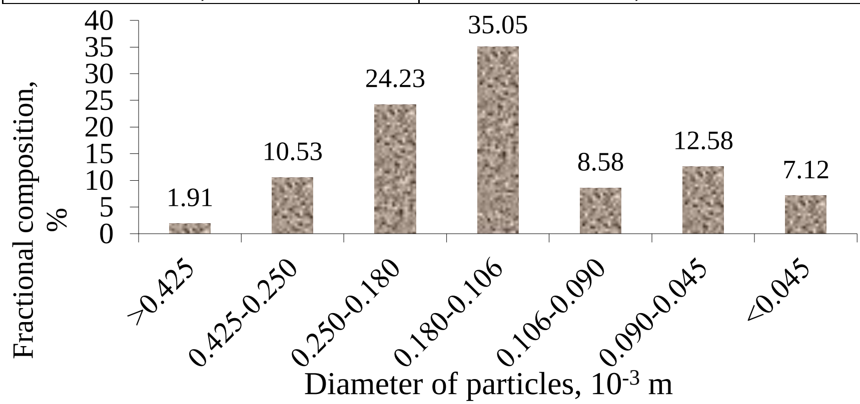

Figure 4. Granulometric composition of a sample taken from the filter section of a sand settling device

MAIN OUTCOMES

1. New construction, repair, and reconstruction technologies and methods for hydraulic structures have been developed:

- A technology for replacing metal beams with reinforced concrete beams in hydraulic structures originally built with metal components has been developed and applied. This innovation reduced repair costs of hydraulic structures by approximately 50%, resulting in an economic benefit of 5 million AZN compared to traditional methods.
- A technology utilizing 12-meter span space beams has been developed and applied for the construction of sea piers. This technology reduces metal consumption by up to 25%, yielding a 25% economic benefit and saving 1.5 million AZN for the specific project, with an expected total savings of 8 million AZN upon full completion.
- A report on a selfelevating floating drilling rig (SFDR), designed for drilling or decommissioning oil and gas wells under offshore conditions, has been developed.
- The “Steel Shirt” method was developed and implemented for restoring metal-pipe support piles. This method was used to overhaul Compressor Station No. 2 (SKS-2) at the “28 May” Oil and Gas Production Department (OGPD), which was in an emergency state. The overhaul extended the operational life of the station by 25 years and achieved an economic benefit of 200 million AZN.
- The feasibility of using a partially constructed support block in the “Guneshli” field was investigated. Following calculations and technical assessments, the block was gradually brought into service and installed as the support block for platform No. 7 at a depth of 148 meters in the Caspian Sea, generating an economic benefit of 17 million AZN.

2. New devices and methods for field development have been introduced:

- More efficient oil-gas-water-sand (OGWS) separators and a new bottom design for oil tanks intended for initial separation of gas, oil, water, and mechanical mixtures from well products were developed and applied in constructing the new Central Oil-Gathering Point (COGP) at Absheronneft OGPD. This resulted in economic savings of 23 million AZN.

- To prevent sand sedimentation in surface transport lines, a new sand settling device was developed and installed at the pump inlet on the stationary deep-sea platform No. 4 in the Guneshli field. From 13 to 21 November 2016, the device collected 450 kg of sand and mechanical mixture.
- An effective calculation method was developed to determine the stress-strain state (SSS) of reservoirs made of nonlinear elastic materials with variable and constant thickness under internal pressure. Calculations using this nonlinear model showed a 14.2% reduction in stress compared to traditional linear models.

3. New device, composition, and methods for developing residual reserves of offshore oil and gas fields have been developed:

- A new seismic-reducing hydraulic piston combined rod pump unit has been developed.
- A new hydrophobic tamponage composition was developed to isolate water flow in wells. Laboratory tests in reservoir models demonstrated the possibility of increasing the compression ratio by up to 19.7% using this composition.
- A corrosion protection method using a high-voltage magnetic field was developed for casing pipes in production and water supply wells. This method was successfully tested in well No. 272 at DDSP-15.

4. The dissertation work contributed new construction methods for hydraulic facilities, devices and methods for field development, novel compositions for developing residual oil reserves, and corrosion protection techniques. Through five applications, a total economic benefit of 253 million AZN was achieved. Additionally, long-standing environmental problems at the central oil-gathering points were addressed, the service life of equipment and transport lines was extended, and the oil compression ratio was increased.

The main outcomes of the dissertation have been published in the following proceedings and academic periodicals

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Personal contribution of the researcher in published works:
The formulation of the research problem, participation in result analysis, and implementation of the studies presented in works [1, 4, 5, 6, 7, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 28, 29, 30, 32, 36, 37] were carried out in collaboration.

The research activities described in works [2, 3, 8, 9, 12, 23, 27, 31, 33, 34, 35, 38, 39] were completed independently.

The defense of the dissertation will be held at the meeting of the BED 2.37 Dissertation Council under Azerbaijan University of Architecture and Construction at 11^{00} on 30 september 2025.

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