ARCHITECTURAL AND ENGINEERING CHARACTERISTICS OF HISTORICAL HYDRO-TECHNICAL STRUCTURES (SARDOBAS) IN CENTRAL ASIA: A COMPARATIVE REGIONAL ANALYSIS

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Abstract

This paper examines the socio-economic importance, structural taxonomy, and hydrological engineering solutions of *sardobas* (traditional domed water reservoirs) across the Jizzakh, Zarafshon, and Kashkadarya regions of Uzbekistan, as well as related sites in Turkmenistan. Operating as critical hubs along the Great Silk Road, these installations secured transit trade and local settlements in hyper-arid zones. Through a comparative architectural and historical analysis, this study maps the metric properties, masonry components, and water supply techniques of key sites including the Yoghochli, Mirzarabot, Malik, Abdullakhan II, and Kasbi Yakka sardobas. The findings demonstrate a highly evolved architectural tradition adapting to micro-regional environmental challenges via advanced masonry methods, structural symmetries, and artificial canal supply lines.

Keywords: *Sardoba, Hydro-technical engineering, Great Silk Road, Kasbi, Raboti Malik, Arid architecture, Central Asian Archaeology.*

Introduction

In the arid and semi-arid zones of Central Asia, water security has historically dictated the trajectory of urbanization, trade dynamics, and migratory routes. Among the most innovative architectural responses to water scarcity was the *sardoba*—a sophisticated, subterranean domed public cistern designed to collect, filter, and preserve fresh water. These structures served as vital infrastructure along the major desert routes of the Great Silk Road, transforming hostile environments into navigable trade corridors.

While general historical chronicles mention these installations, comprehensive regional comparisons of their architectural metrics, localized hydrological mechanics, and evolutionary timelines remain fragmented. This research aims to fill this gap by evaluating the architectural typologies and engineering systems of sardobas located between the Jizzakh and Syrdarya regions, the Zarafshon valley, and the Kashkadarya oasis (specifically the ancient trade hub of Kasbi). By linking structural variations to localized environmental resources—such as shifting from direct precipitation capture to complex artificial canals—this study provides a systematic overview of historical hydraulic engineering in the region.

Methods

This research utilizes a multi-disciplinary methodology combining historical-comparative analysis, architectural typology mapping, and a review of archaeological field data. The structural and metric descriptions analyzed in this study are compiled from:

Archaeological survey records conducted in 1996 by M. Pardaev and S. Suyunov in the Jizzakh-Syrdarya interfluve [1].

Excavation profiles from the 1990 Raboti Malik caravanserai expedition led by N.B. Nemtseva [2].

Recent field research conducted by the Institute of Archaeology of the Academy of Sciences of Uzbekistan at the Yakka Sardoba in the Kasbi district of the Kashkadarya region [8].

Archival geographical and geological accounts from late 19th and early 20th-century researchers and travelers, including A. Lehman (1841–1842), I.L. Yavorsky (1878–1879), and M.M. Reshetkin (1928) [5, 6].

Results

The Jizzakh–Syrdarya Steppe Corridor

In 1996, researchers Mukhtor Pardaev and Samaritdin Suyunov investigated the construction history, chronology, and architectural styles of reservoirs situated

between Jizzakh and the Syrdarya river [1]. A prominent installation in this desert oasis zone is the Yoghochli Sardoba, located approximately 35 km north of Jizzakh city.

Architecturally, the Yoghochli sardoba features a semi-spherical dome built with precise, square-shaped baked bricks measuring 26×26×5 cm and 27×27×5 cm. The layout consists of a cylindrical wall system supporting the superstructure. Structurally, the foundation base tapers from a width of 1.25 m at the bottom to 0.55 m at the upper rim. The reservoir exhibits a total height of 11 m, an internal dome diameter of 15.35 m, and a water basin depth of 5.50 m. For usability, a staircase consisting of more than ten steps descends directly into the basin. Water enters via a specialized inlet device known locally as a *"qulfak"*, which funnels water safely into the pool while preventing excessive siltation, while ventilation holes built into the upper vault regulate humidity and airflow. The entrance is marked by a prominent arched doorway standing 2.90 m high [1].

Further north, two related structures demonstrate the density of this network: the Mirzarabot Sardoba (25 km north of Yoghochli) and the Yakka Sardoba of Jizzakh (an additional 25–30 km north). While sharing structural concepts, these units vary significantly in size, total elevation, and basin depth. Notably, their water sources differed: Yoghochli and Mirzarabot relied purely on the collection of seasonal snowmelt and rainwater, whereas the northern Yakka sardoba was fed directly via artificial irrigation channels drawn from the Syrdarya river [2].

The Zarafshon Valley and the Karakhanid Legacy

Moving westward into the Zarafshon valley, hydro-technical engineering was frequently paired with monumental state architecture. A prime example is found 17 km west of the historic city of Karmana along the Samarkand–Bukhara route: the Raboti Malik caravanserai and its accompanying Malik Sardoba.

The complex served as a fortified summer residence for the Karakhanid sultans. Archival evidence of its state of preservation in the 19th century is preserved in the detailed sketches and travel diaries of the Russian scientist and

artist A. Lehman during his 1841–1842 expedition. Archaeological excavations directed by N.B. Nemtseva in 1990 confirmed that the caravanserai was erected in the second half of the 11th century by the ruler of Bukhara, Shams al-Mulk Nasr ibn Ibrahim (1068–1080). The immediate proximity of the massive Malik sardoba to this Silk Road fortress emphasizes its role in securing royal, military, and commercial logistics.

Comparative Architecture: The Abdullakhan II Typology

To understand the technical evolution toward the 16th century, comparisons can be drawn with the exceptionally preserved Abdullakhan II Sardoba in Turkmenistan, located 18 km from the Chorshanba railway station near a historical settlement site.

This structure features a tiered wall and dome design using standardized 27×27×5.5 cm baked bricks. It stands 10 m high with an internal diameter of 12.5 m, built upon a heavy limestone foundation. The dome features three symmetrical arched windows (1.5 m high by 1.0 m wide) and four distinct entry portals. Its hydrological mechanism consists of a specialized closed catch-hatch running along the base perimeter to gather surface water, which is then cleanly conveyed into the central basin via a long, narrow pipe structure [3]. As highlighted by archaeologist M.E. Masson, the vast majority of these high-tier structures in the region date back to the reign of Abdullakhan II, showcasing a highly unified 16th-century architectural tradition utilizing refined gypsum (*ganch*), brick templates, and standardized mortar recipes [4].

The Kashkadarya Oasis and the Kasbi District Excavations

The southern network in the Kashkadarya valley demonstrates an identical reliance on massive water storage units. In the lower reaches of the valley lies Kasbi, recognized by classical geographers Istakhri and Ibn Hawqal as a dominant urban center of Southern Sogdia. Situated roughly four *farsakhs* from Nasaf (Karshi) along the Bukhara–Balkh trade route, Samanid-era Kasbi housed a large Friday Mosque and acted as a bustling trade hub.

The water demands of this urban center are reflected in the discovery of the largest sardoba in the Kashkadarya valley, situated in the shakhristan (city proper) close to the ancient citadel (*ark*). Across the wider Karshi steppe, historical records list an extensive network of reservoirs: Urachi, Talimarjon, Egizak, Chorcha, Yusuf, Karshi, Fatto, Ashun, Begicha, Shorcha, Nishon, and the Kasbi Yakka sardoba.

The Yakka Sardoba of Kasbi, initially documented in 1928 by hydrogeologist M.M. Reshetkin [7], stands out as the best-preserved specimen in the district. Recent excavations by the Institute of Archaeology have brought to light its explicit physical parameters:

Superstructure Geometry: Designed with a distinct crescent/semi-spherical profile, the walls and vault are composed of baked bricks measuring 24×24×5 cm and 26×26×5 cm.

Vertical Profile: The structure reaches a total height of 9 m, engineered sequentially in seven concentric, circular tiers leading up to the apex.

Apertures & Symmetries: It contains four large arched windows (1.10×0.8 m) arranged in a perfect symmetrical layout. Directly below each window is a matching, minor arched ventilation slot.

Basin Dynamics: The sub-surface pool begins precisely at the interior foundation ring, showing a diameter of 14 m and a depth of 4 m. Light is cast directly down into the water via a circular oculus/skylight cut into the very top of the dome. The main arched entry doorway measures 2.60 m in height [8].

Discussion

The comparative metric data compiled across these regional structures reveals a deliberate, highly calculated engineering standard shared by Central Asian builders across centuries, as summarized below:

Sardoba Site	Region / Location	Main Water Source	Dome Diameter	Basin Depth	Total Height	Brick Dimensions (cm)
Yoghochli	Jizzakh Oasis	Snow & Rain	15.35 m	5.50 m	11.0 m	26×26×5 / 27×27×5
Abdullakhan II	Turkmenistan	Catchment Hatch	12.50 m	*Variable*	10.0 m	27×27×5.5
Yakka (Kasbi)	Kashkadarya	Artificial Canals	14.00 m	4.00 m	9.0 m	24×24×5 / 26×26×5

A major challenge identified in historical accounts was maintaining these pools in hyper-arid plains over long periods. Late 19th-century observations by traveler I.L. Yavorsky indicate that many sardobas in the Karshi steppe had fallen into disrepair due to severe water-delivery challenges, noting that relying purely on seasonal rain and snow frequently failed to meet the needs of trade caravans [5].

To combat this, historical engineers shifted from passive catchment to active hydraulic modification. Geologist M.M. Reshetkin documented that the Yusuf Sardoba in the Karshi steppe was supplied by an artificial canal explicitly dug from a water source 15 km away [6]. Similarly, the regional masterpieces of the 16th century—the Qush and Bozachi sardobas built under Abdullakhan II—were sustained by long feeder channels branching out directly from the main flow of the Kashkadarya River [6]. This reveals that the preservation of water inside the sardoba depended heavily on external irrigation engineering.

Conclusion

The systematic architectural and archaeological assessment of historical sardobas throughout the Jizzakh, Zarafshon, and Kashkadarya regions yields several definitive conclusions regarding ancient Central Asian hydro-engineering:

Topographical Optimization: Initial construction phases strictly evaluated local terrain levels, selecting flat, optimal topographic depressions that naturally favored regional water convergence.

Subterranean Excavation: The central storage basin (*havza*) was intentionally established below the natural ground surface level, excavated deep downward to optimize thermal insulation and minimize water evaporation.

Ergonomic Access: Following basin excavation, builders integrated a highly functional, reinforced multi-step masonry staircase positioned at a calculated location to allow users safe, direct access to fluctuating water levels.

Hydrological Adaptability: Reservoirs utilized multi-source filling mechanics, combining passive seasonal collection (rain and melted snow) with active feeder infrastructure, including artificial open canals and subterranean *karez* (aquifer tapping) lines.

Durable Materials: Structural longevity in high-humidity interior environments was achieved by utilizing high-density square baked bricks, dressed stone foundations, and premium local gypsum (*ganch*) blocks.

Advanced Binding Mortars: The structural integrity of the massive domes and water-retaining walls was secured through specialized alabaster formulas and localized hydraulic cements processed from finely crushed, calcined stone aggregates.

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