FULL SCALE REPLICA OF THE YENİKAPI 12 MEDIEVAL SHIP

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The Yenikapi 12 (YK 12) shipwreck was uncovered in 2007 in the course of salvage excavations at the Theodosian Harbor; one of the most important Byzantine harbors on the Marmara coast (Fig. 1). The shipwreck was lifted after in situ recording and placed in fresh water pools of Istanbul University Yenikapı Shipwrecks Research Center, where their full scale drawings of the hull members, cataloguing and documentation were completed. It contained numerous intact amphorae and amphora-shards. Towards the stern there was a partition which contained the personal belongings of the captain. The partition contained a portable stove and its lid, a cooking pot, tankard and jugs, two amphorae, olive stones and cherry pits in a basket. Such personal belongings, which are rarely encountered in shipwrecks, are of special importance for they provide information on the anchoring port and the captain’s nationality. Cherries ripen in May and June in Marmara region and their presence shows that the vessel sank due to a summer storm.

Fig. 1: YK12 shipwreck (In situ)
Based on a coin found within the wreck context, the shipwreck has been dated to the 9th century AD; results of the 14C analysis of the woods from the boat give a date range between 672 and 870 AD. These data make it plausible that YK12 was in the Theodosian Harbor in Constantinople in the 9th century AD, when maritime trade in the Byzantine Empire shifted to the north, towards the Black Sea, and when economy and trade were beginning to revive.

For what purpose did this small trading vessel come to the harbor, and why did it sink inside the harbor? Pits of cherry and peach, which grow in the Marmara Region in May and June, found in the wreck allow us some interpretation. Could this small vessel have brought food and drink for the festival to celebrate the foundation anniversary of the city in May? These months also correspond with the Lodos wind season. Perhaps the captain had unloaded his cargo and then stocked his vessel for the new route with seasonal fruit such as olives, cherries, and peaches, drink, and the Byzantine staple food, bread. It seems highly probable that the vessel sank immediately after leaving the pier, or after proceeding a short distance within the harbor, but before passing the breakwater. Experts think that the vessel was covered by resettling sand raised from the sea bottom in the high-energy environment during a big storm. The presence of cherry pits in shipwrecks found on the same level supports the hypothesis that some of the other vessels also sank during the same storm. Since the vessel was at least partially covered by sea sand immediately after this unfortunate event, most of the amphorae remained in situ without scattering over the sea bottom. The personal belongings and supplies of the captain in the special covered compartment and most of the hull planking of the vessel remained right where they sank, under the sea sand and the layer of alluvium accumulated by the Lykos River; they were excavated approximately twelve centuries later, in the course of the collaboration of the İstanbul Archaeological Museums and İstanbul University.

From the Excavation Site to Documentation

Documentation work on the wreck was carried out in two main phases: in situ documentation occurred without disturbing the integrity of the hull, and documentation of each piece separately was done in İstanbul University’s Yenikapı Shipwrecks Research Center.

The field work on YK 12 conducted by İstanbul University started with the construction of a temporary shelter to protect the remains of the hull from weather conditions. Through measurements taken without moving the wooden members of YK 12, documentation towards establishing the volume of the hull, the curves of the frames, the angles of the keel, the stem and the sternpost, and the relationship among the members was completed in order to grasp the entirety of the vessel. To this end, a team of experts recorded the mass of the body of YK 12 in 3D with the help of a Total-Station, made photo-mosaics, and executed measurements, illustrations, visual evaluation and photography work hand in hand (Fig. 2, 3, 4). Following the documentation work, members of the wreck were dismantled, lifted on molds prepared
according to the original form, and placed in crates prepared based on their measurements. Then, the wooden members in the crates were transferred to salt removal pools and passive conservation methods were applied.

Fig. 2: Total station measurements of Yenikapı 12 (left).
Fig. 3: In situ drawings of planks (right).

Fig. 4: PhotoMosaic image of YK12

Following this step, all wooden members of the vessel were documented with the help of a FaroArm digitizer device and recorded in 3D in the digital environment (Fig. 5). Detailed analyses of the wood finds resulted in significant information, such as the standard units used in the vessel’s construction, the marks of the shipwright, the tools he used, and what part of a tree was used for the wooden members (Fig. 6). As a result of three years of evaluations, the dimensions of YK 12, its design principles, structure, and construction sequence were identified and hypotheses developed about the locations and shapes of its missing parts. These data facilitated reconstruction drawings of the vessel, which were then fleshed out, and
illustrations and animations of the vessel on the sea and in the harbor have been prepared. The conservators decided to use polyethylene glycol (PEG) 2000 impregnation and freeze-drying procedure to conserve the vessel. Currently, PEG applications on the wooden members continue.

![Image of conservators working with wooden objects]

**Fig.5** Digital drawings of ship members by Faro-Arm device (left).
**Fig.6** Consultation of ship building technique (right).

**From Tree to Vessel**

The analyses of the wood from YK 12 show that five different tree species were predominantly used in the construction of the vessel. Trees with different properties were selected to supply the strength suitable for their respective use. Hull planking was made entirely from chestnut (*Castanea* Miller/ *Castanea sativa* Miller). Ash (*Fraxinus* L.) was used for the futtocks and the mast step, and red oak for tree nails. Floor timbers were made of oak (*Quercus* L.) and walnut (*Juglans* L.), the keel of oriental beech (*Fagus orientalis*) and hornbeam (*Carpinus* L.), pegs of hornbeam (*Carpinus* L.), the wale and ceiling of oak (*Quercus* L.). Although oak tree has a wider distribution area, Anatolian chestnut, ash and red oak tree belong to the Black Sea region. The fact that hornbeam and walnut trees grow in the Black Sea, Marmara and Aegean regions suggests that the wood used in the construction of the vessel was brought from Northern Anatolia.
How was this material shaped? We can understand this process by looking at the shape and fiber structure of the wooden members. According to our evaluations, the shipwright used the trunk and one branch of one tree for two floor timbers that form the part of the skeleton of YK 12 (Fig. 7). The dimensions of the log to be cut depended on the properties of where on the vessel it would be used. For example, to shape an oak floor in the middle of the vessel, a tree with a trunk that was at least 2 m tall and measured 20 cm in diameter, with a branch that extended from the trunk at an angle of approximately 120° and measured at least 18 cm in diameter was used.

![Fig. 7: A frame sawn from a tree trunk](image)

Tool marks on the surface of the members tell us about how the shipwright used the saw, the axe, the adze, and the drill. For example, on one side of the frame there exist only saw marks, whereas on the other side there are axe and adze marks that have erased the saw marks (Fig. 8). These marks lead to the interpretation that, after the floor timbers were cut and shaped with the help of a saw, one face was smoothed by an axe or adze, and chamfers were worked, while the other face was left as it is. Similarly, tool marks reveal that the keel, stem and sternpost joints were cut with a saw and smoothed with an adze and chisel. Drill marks are very distinct in the holes made for tree nails. It is thought that these holes were made with a drill similar to special drills of various sizes found in the Yenikapi excavation area, which were rotated by a thread and used particularly in ship-building.
Construction Details and Assemblage Sequence

The construction of the vessel indicates that two different building techniques were used. The keel and the posts are joined by keyed hook scarves. Garboards were placed and nailed on the lines of the rabbets on both sides of the keel (Fig. 9). Long planking, shaped when necessary, are held together by S-shaped scarf joints (Fig. 10); they were fastened by regularly spaced edge-dowels placed on their side surfaces along the whole hull and mounted up to the level of the first wale. These constitute the primary evidence that the vessel was built according to the shell-based principle.

Fig.8: Tool marks on ship timbers

Fig.9: Garboard-keel attachment (left).

Fig.10: S scarf in a planking strake (right).
Even though the wreck bears many features of shell-based building, the framing pattern of YK 12 exhibits evidence for a frame-based hull, as it is still used today. In this pattern, the long arms of the floor timbers alternate between starboard and port (Fig. 11). Floor timbers and futtocks, put together by L-shaped joints, and support the transversal strength of the vessel, while also forming the superstructure of the hull. The first wale, which is not fastened to the planking above or below, makes up the most important evidence that the building technique has changed, just like the Mediterranean shipwrecks built in mixed construction technique in other centuries. The mast step that functions as keelson, stringers, wales, and the ceiling nailed to the frames function to balance the coexistence of two different techniques and to increase longitudinal strength.

![Fig.11 Framing pattern of YK 12.](image)

To summarize, this small cargo vessel, where old and new technology were used together, represents a phase in the transition from shell-based to frame-based construction and proves that shell-based construction technique was still not forgotten in the 9th century AD.

As a result of detailed studies of the hull members, it has become clear that, after joining the keel and the posts, the shipwright mounted the first five hull planks before the frames. A few of the floor timbers may have been placed in order to support the shape of the hull and to facilitate easier assembly. However, most of the floor timbers were added after the eighth strake. At this point, the shipwright finished the hull structure with the first wale, ended the
building in the old technique, and mounted the remaining floor timbers and futtocks. The ninth planking strake and the other strakes were laid on these frames and nailed. After the mast step was placed on the frames, the ceiling was nailed on the floor timbers. In the following steps of the assembly, the upper members of the hull, the rudders and the sails were mounted.

**From Wreck to Replica**

A 7-meter-long and 2.3-meter-wide portion of the hull has survived. Because the boat sank at a slight angle on its hull and was suddenly covered by sand, part of the amphorae cargo, and therefore most of the wooden members under this cargo, were preserved completely and *in situ*. Its keel, stem and sternpost, eight planking strakes on the port side and nine planking strakes on the starboard side, two wales on the starboard side, part of the bulwark, 25 floor timbers, 15 futtocks, the complete mast step, and 43 ceiling timbers have survived (Fig. 12).

![Fig.12: Plan drawing of YK12](image)

Of course, it is impossible to know exactly how the shipwright imagined the vessel in his mind, how he designed it, or the development process of the boat’s construction based on these remains. Nevertheless, data such as the marks that the shipwright made on the wooden members while he was shaping and placing them, the details of the wooden members, and the empty nail holes and impressions of missing pieces have helped us to understand the system. This vessel was built based on a series of precise rules and repetitions, using high-quality materials brought especially for the purpose, and by a competent shipwright. The information we obtained from the skill and almost obsessive care of the shipwright, as well as the presence in the Yenikapı excavation area of several other wrecks very similar in terms of size, form and construction, have increased the precision of our reconstruction work. Accordingly, we have shaped a hypothetical form by adding reconstructed elements on to the original parts of the hull of YK 12, 60 per cent of which have been preserved.
A reconstruction drawing was made by both using the in situ ship timbers and additional fragmented timbers that were not found in their original locations. In order to do so, 3D AutoCAD drawings based on in situ Total Station measurements and 1:1 scale FaroArm digitizer drawings were combined (Fig. 13).

Fig.13: Drawing of frames

At this stage of the study, it has been investigated that how the available information with a high degree of accuracy can be enriched in the first place. Considering the necessary symmetrical arrangement of both sides of the ship, the hull lines of the starboard side were applied to the port side through plan and section drawings. A 1:10 scale research model and a 1:10 scale in situ model were made for facilitating three dimensional observations and providing more accurate reconstruction work. (Fig. 14). Besides, the designated hull lines were verified on scale models.

Missing parts of the YK12 hull, symmetrical completions, frame pattern, hull planking lines, angle definitions, proportional increase and the upper structure were determined on the basis of various clues such as nail holes, through beam slots and bulkhead arrangement at the stern.
According to the reconstruction results, YK 12 was a small trading vessel approximately 9.20 m long and 2.54 m wide, suitable for coastal navigation. It traveled with a single-mast lateen sail and was controlled by two quarter-rudders characteristic of that period. It had a special compartment closer to the stem, a foredeck, side-deck, and a poop deck. The hold was open on top and probably closed with a tarp to prevent sea water from splashing into the vessel (Fig. 15). The bow and the middle parts where the hold was located, as well as the flat frames and curved hull, were built wider than the stern a design that increased loading capacity. It carried 180-250 amphorae in its hold, which were 80 cm high and 3.20 m long on the average. Moreover, the flat-framed hull shape increased the boat’s ability to enter easily into shallow harbors and bays, and the wider form of the bow increased its capability to cope with high waves.
Fig.15: Side view, section and plan drawings of YK12.
Following the reconstruction studies, drawing of hull lines and sections, preparations have been made for the full scale replica of YK 12 (Fig. 16). The replica is being built at RMK Marine shipyard in İstanbul; one of the pioneer companies of Turkish shipbuilding industry. Construction team includes İstanbul University’s Conservation of Marine Archaeological Objects Department staff, experienced carpenters, ship designers and experts.

**Fig.16: YK12 Hull lines**

The design of the hull form of the replica is based on the actual remains of the shipwreck. A complete set of hull lines was generated by a combination of total-station measurements, digitizer and hull line drawings, and scaled model-building. Missing information about the ship was gleaned from both iconography of the period and reconstructions of contemporary shipwrecks. Reconstruction data was processed with digital software providing hydrostatic values, stability curve, load distribution, load center calculations and volumetric analysis. (Fig.17). Other data such as planking dimensions, planking and frame joint locations, framing pattern, ceiling pattern, bulkhead arrangement, through beam locations and deck height were defined in detail.
After the completion of all necessary data, chestnut trunks 4.5 m in length and 50 cm in diameter on the average were provided. (Fig.18).

**Fig.17:** Dimensions of the main hold and the stern hold of the ship

**Fig.18:** Chestnut timbers and trunks
In order to remove excess water, the sliced chestnut trunks were dried in a controlled procedure (Fig.19, 20, 21, 22). During this two months procedure, construction housing about 15 m long and 6 m wide has been set up at RMK shipyard facility.

**Fig.19:** Slicing the chestnut trunks
Fig. 20: Sawn chestnut trunks
Fig. 21, 22: Removal of excess water
The full scale drawings of the keel and the frames were printed and their molds were made. These molds guided shipwrights to cut out timbers in desired forms (Fig. 23, 24).

Fig. 23, 24. Frame molds
The construction began with setting up the keel. Keel pieces sawn according to the moulds were joined through hook scarves, also supported with wedges and stretched with a central cord in order to prevent instability (Fig. 25). The construction was made according to the original hull shape, dimensions and tree species. While the planking strakes were sawn from chestnut, oak was used for the frames. Frame-plank joint locations, keel, plank and floor-futtock joint forms, planking pattern was built according to the original ship. (Fig.26, 27).

![Setting up the keel](image)
Fig.26: S scarf and nail holes on a plank (above).
Fig.27: Hook scarf on keel (below).
The construction continued with inserting the frames on the keel then hull height and locations of the wales were determined through battens (Fig.28). Following the installation of the bulwark and upper wale, the planks were nailed to frames and joined to each other through scarves (Fig. 29, 30, 31, 32, 33). After the completion of the planking strakes that forming the shell, inner construction elements such as through beams, bulkhead, mast step and the ceiling strakes were installed. An old massive telephone pole was used as a secondary construction material for the mast itself with a circular section. The rigging and sailing canvas were provided by the support of sailing experts.

**Fig.28:** The battens determining the hull shape
Fig. 29: Bulwark detail

Fig. 30: Joining the hull planking strakes
Fig. 31: Inserting the hull planking

Fig. 32: Bulwark installation
Ancient ships hold great potential to inform us about the past. On the one hand, they reflect general aspects of society such as technology, communications, trade, settlement and even cults. Thereby, this replica construction is aimed to inform students, both professional and amateur researchers as an educational item. In doing so all the construction phase has been documented with timelapse shootings through GoPro camera, besides a documentary by Istanbul University’s Faculty of Communication Sciences has been prepared. The documentary is expected to be completed after launching ceremony of the ship in May 2016. It is important to note that although the material and design of the replica is based on the actual remains of YK 12 shipwreck, this study should not be considered as an experimental archaeology project. Rather it aims to perceive a 9th century ship with its original form and dimensions as a physical visual source. Future exhibitions at both national and international museums and sailing experiences have been planned (Fig. 34).
Fig. 34: The illustration of YK 12 sailing