Recovery of Fragile Objects from Underwater Archaeological Excavations: New Materials and Techniques by SASMAP Project

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Abstract. Underwater archaeological excavation represents a traumatic and essentially destructive event in the history of artefacts, especially organic, and its underwater context. Indeed, due to their fragility, organic archaeological materials from underwater sites can be challenging to excavate, support, raise and transport to conservation facilities. This is due to the inherent difficulties of working underwater (limited time and potentially harsh conditions) and in particular the crucial stage of lifting artefacts from the seabed to the surface where mechanical damage can easily occur. Block lifting of fragile archaeological materials is a useful procedure often adopted on land excavations and allows the collection of information which could be irretrievably lost during more rapid excavation. This procedure could be used with success to recover fragile objects on an archaeological underwater excavation thanks to the new materials and techniques tested and adopted in the SASMAP project (http://sasmap.eu) as will be discussed.

Keywords: Underwater archaeological excavation, recovery, block lifting, organic, waterlogged, fragile artefacts, frame, carbon fibre, tape, synthetic polyurethane resin, Super Absorbent Polymer, Freezing method, SASMAP project.

1 Introduction[1]

Underwater archaeological excavation represents a traumatic and essentially destructive event in the history of artefacts, especially organic, and its underwater context. Indeed, due to their fragility, organic archaeological materials from underwater sites can be challenging to excavate, support, raise and transport to

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conservation facilities. This is due to the inherent difficulties of working underwater (limited time and potentially harsh conditions) and in particular the crucial stage of lifting artefacts from the seabed to the surface where mechanical damage can easily occur. Block lifting of fragile archaeological materials is a useful procedure usually adopted on land and allows the collection of information about materials and elements which are at risk of being irretrievably lost during more rapid excavation [1], [2]. In each underwater archaeological excavation different methods are adopted to support and lift finds including: special containers with a lid and lined with protective foam, flat sheets, steel baking-trays, or polyethylene box-lids, self plastic bags, bubble-wrap, plastic string or cotton ties, purpose build-pallets, large trays to support boxes or bags or large objects etc.. The waterlogged organic materials, including very fragile and small artefacts and large objects such as hull remains or components, log boats, fish traps need special care because of their state of preservation [3],[4],[5].

This interesting topic was enhanced in the SASMAP project, *Development of Tools and Techniques to Survey Assess Stabilise Monitor and Preserve underwater archaeological sites*.[2] [6]. In particular, the work package number five titled *Tools and techniques to raise waterlogged organic archaeological artefacts* was devoted to this stimulating branch of research and involved some of the partners of the Consortium, The National Museum of Denmark, coordinated by David Gregory, The Viking Ship Museum, coordinated by Jørgen Dencker and the Superior Institute for Conservation and Restoration (ISCR-MBACT), coordinated by Barbara Davidde Petriaggi. The research draws upon the extensive excavation and lifting experience of The Viking Ship Museum and the researches into stabilising and consolidating archaeological remains underwater of the ISCR- MBACT [7], [8], [9] and The National Museum of Denmark in order to develop best practice methods.

2 Materials and Techniques to Recover Fragile Artefacts

The objective of the research was to look at the feasibility of innovative methods to lift complex and fragile organic artefacts and to find new materials to stabilize fragile organic artefacts in a sediment block and to facilitate their raising and transport to conservation facilities.

Five different methods were tested:

1. a lifting frame for sediment block containing complex and fragile organic artefacts (designed by The Viking Ship Museum)
2. sheet of carbon fibre in a plastic bag vacuum (designed by ISCR-MBACT)
3. 3M™ Scotchcast ™ Plus Casting Tape
4. A Super Absorbent Polymer
5. freezing method (tested by The National Museum of Denmark).

[2] The project SASMAP has been funded from the European Commission under the Environment working theme, ENV. 2012.6.2-6. Development of advanced technologies and tools for mapping, diagnosing, excavating and securing underwater and coastal archaeological sites. For more information on the project see `http://sasmap.eu`

Two different materials in sections 3 and 4 have been tested for the first time in the underwater archaeological field by ISCR-MBACT:

2.1 The Lifting Frame

Based upon previous experience conducted by The Viking Ship Museum from earlier attempts at raising complex and fragile organic artefacts (log boats, fish traps) a new type of "raising" equipment has been developed.

For testing purposes it was decided to make a lifting frame of a size and quality that actually can be used for lifting sediment blocks of a size up to 100x40 cm. The lifting frame is partly modular in the sense that it has a separate bottom and top part that are connected with vertical posts whose length can be varied. This means that the height of the frame is adjustable depending the thickness of the sediment block; this can vary significantly depending on both the shape and structure of the artefact that is to be raised and the type of sediment and the stabilization of this. The vertical modular construction of the lifting frame ensures easy access to excavate the block under safe conditions in the laboratory because the top parts as well as the vertical iron posts are removable. At one end of the bottom part of the frame a removable hydraulic cylinder has been mounted (can be mounted and dismounted), a piston is used to press thin iron plates that effectively undercut the sediment block. The plates run in tracks at the inner side of the long sides of the frame. On this first lifting frame a manual hydraulic pump will be used. In the longer term the hydraulic pump will be run by an engine on board a boat.

Fig. 1. The lifting frame. Photo VSM.

Once the sediment block has been undercut removable/loose side plates are mounted securing the sides of the sediment block. The upper/top surface of the sediment block and the exposed part of the artefact are then covered by stable (soft) material topped with a plate to protect it against damage during the lift through the water column and especially when breaking the water surface which is the most critical part of a lifting process at the sea. Both the bottom and the top part of the frame have been mounted with lifting eyes spreading the weight evenly on the frame during the lifting process. The bottom and top part of the frame are constructed on the basis of 40x40 mm square electroplated iron profiles while the vertical posts are 25 mm in diameter. The total length/width of the frame is 197/52 cm. This frame ensures that artefacts / sediment sections can be raised as a complete unit, without having to be cut into smaller fragments. Furthermore, it will be designed so that excavation can take place in a controlled manner and subsequently be completely secure during the raising, transport and following excavation in the laboratory (Fig.1).

2.2 Sheets of Carbon Fibre in a Plastic Bag Vacuum

A new procedure designed by Marco Ciabattoni (Physics Laboratory ISCR-MBACT) using composite material as sheets of carbon fibre, previously treated with cured epoxy-time, in a plastic bag vacuum was tested to lift fragile artefacts. The ISCR Physics Laboratory has used for the first time carbon fibre and Kevlar to realise a protective device for the bronze statue of the Dancing Satyr of Mazara del Vallo, in occasion of transporting and exhibition at the Italian Pavillon EXPO 2005 (Aichi) and at Tokyo's National Museum. The shell was intended to contain and protect the statue after the ISCR restoration directed by the archaeologist Roberto Petriaggi, like a case for a precious cello, whenever it is moved [10], [11], [12]. The term "composite material" indicates the product obtained by the association of different materials, such as fibreglass, constituted by a matrix, which is the resin, which aggregates a reinforcing fibre. The result is a strong yet light material that can easily take on intricate forms from even the most complex of moulds. Composite materials are part of a large family of engineering materials of great applied and technological interest. Their exceptional properties, as alternatives to traditional materials, have opened up new horizons in many areas. In a few short decades the emergence of these materials has radically changed engineering, and these technologies are now an integral part of how we work. The outstanding properties of composite materials derive from the synergy between the two constituents: the resin and the reinforcing fibre. Resin does not itself have the properties needed to ensure the mechanical strength of a structure. To meet appropriate specifications, it needs the reinforcement provided by the fibres. Fibres in turn need resin as a matrix. Individual fibres have a specific breaking strength. With the resin acting as a cohesive agent, the load is distributed across the fibres and limits their extension. This allows the fibres to work together to give a greatly increased breaking strength. The structures used in the SASMAP project to provide support and protection during the recovery of artefacts on the underwater archaeological excavation are made using appropriately prepared carbon fibre. Structures can be simple or laminate according to the degree of robustness and rigidity required for a particular recovery operation. The base structure is produced using a vacuum bag made of two polypropylene sheets bonded with a high-adhesion sealant. The bag serves not only to create a vacuum but also, for our purposes, to isolate the carbon structure from the underwater environment. Inside the vacuum bag there is a sandwich-structure composite, consisting of: an aerating felt that absorbs excess resin and, depending on its thickness, serves as a soft contact layer; a peel ply[3]; an impregnated carbon fibre laid up as required, and peel ply again (Fig.2 A). The use of Sheet of carbon fibre in a plastic bag vacuum was tested both, in ISCR-MBACT Laboratory, and in the field during the excavation works conducted by Soprintendenza per i Beni Archeologici dell'Etruria Meridionale, directed by Patrizia Petitti, at the Iron Age Village "Gran Carro" (Bolsena lake).

The results of the tests confirm that the carbon fibre fabric, impregnated with epoxy resin, is a real shell of protection that adheres to surfaces, protecting the

[3] A release fabric to allow the venting of excess resin. It is easily removable and leaves a roughened surface suitable for further bonding.

artefact by rapid drying and preventing possible trauma due to the poor state of preservation of the material (Fig.2 B). A good characteristic of this system is that it could be used for small and large artefacts (light and heavy), with or without sediment, because it is a modular system that can be adapted to many different conditions (depending on the state of conservation of the artefacts, environmental situations etc.). Furthermore, it may also act as an effective container for temporary storage of waterlogged organic artefacts.

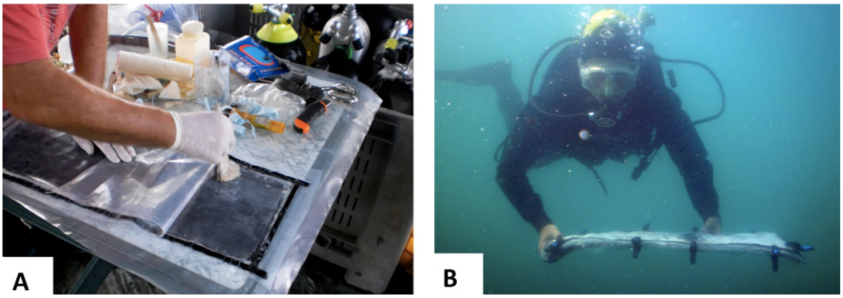

Fig. 2. A: the preparation phase: inside the bag an epoxy resin was applied over the multilayer then the bag was closed. B: The restorer brought to the surface the fragile artifacts recovered with sheets of carbon fibre in a plastic bag vacuum. Photo ISCR –MBACT.

2.3 3M™ Scotchcast ™ Plus Casting Tape

To develop new materials to stabilize fragile organic artefacts and facilitate their raising and transport to conservation facilities, the ISCR – MBACT (Marco Ciabattoni and the restorer Riccardo Mancinelli external collaborator of ISCR-MBACT) have tested a material easily available on the market: the 3M™ Scotchcast ™ Plus Casting Tape. This is a lightweight, strong and durable casting tape used in orthopaedic field that combines the benefits of a fiberglass casting tape with the handling ease of plaster. The tape (bandage) contains a synthetic polyurethane resin which, in contact with water or simply exposed to moist air, hardens, enabling immobilization of fragile artefacts yet being extremely lightweight and durable. In the ISCR Physics Laboratory the 3M™ Scotchcast ™ Plus Casting Tape was tested in a tank with sea water, then its effectiveness was validated underwater in the village "Gran Carro" (Bolsena Lake). At the end of tests the product results is easy to use to recover a wooden fragile archaeological object. Moreover, the 3M™ Scotchcast ™ Plus Casting Tape is environmentally friendly and it is easily removed post lifting (if it is in direct contact with the archaeological find too). This product is useful for first aid interventions because it is easy to find on the market but it has the limitation that it can only be used for small objects. In fact, the maximum size of the tape measures 4 metres X 10 centimetres (Fig.3).

Fig. 3. Test in ISCR laboratory. On the right a basket recovered with 3M™ Scotchcast ™ Plus Casting Tape; on the left a basket recovered with sheets of carbon fibre in a plastic bag vacuum. Photo ISCR –MBACT.

2.4 Water and Sediment Consolidation System

The ISCR –MBACT is testing a system to transform into a gel the water and the sediment that incorporate the fragile archaeological find, in order to lift it back in complete security. This test was conducted in the Laboratory by Giancarlo Sidoti, chemist of ISCR –MBACT and by the research collaborator Gabriele Gomez De Ayala. A Super Absorbent Polymer, modified to absorb salt water and sediment, with a controlled molecular expansion and controlled hardness was tested. [4] The amount of crosslinking agent used is 1/4 by weight. By varying the crosslinking agent it is possible to change the properties of this polymer as the water solidification time (from 10 seconds up to minutes), the polymer expansion volume and the hardness of the water gel.

The system is developed in the following phases:

1. the polymer is obtained in the laboratory, then it is taken underwater in a waterproof box;
2. the polymer is distributed underwater all over the area that needs to be transformed into gel, where the fragile archaeological artefact is lying;
3. when the water and the sediment have been transformed, the gelled block composed by organic fragile artefacts and sediment can be carried up to the surface;
4 the gel can be reversed by using a ionized water solution with no damage for the artefact.

In June and September 2014 the tests has been carried out underwater, in the Marine Protected Area, Underwater Park of Baiae and the test, still in progress, regards the

[4] Basic polymers: acrylic acid and acrylamide. Acrylic acid structure: CH2=CH-COOH - Methylenebis-acrylamide (MBA), crosslinking agents* (to partially neutralize the acid groups).

crucial phase of transport and distribution of the Super Absorbent Polymer underwater. This system, as emerges from the conclusions, seems to be very promising.

2.5 Freezing Method

The innovative method described at the point 2.4 provides the recovery of the fragile artefact encapsulated in the block of sediment and has some conceptual similarities with another method using freezing tested by The National Museum of Denmark. The Danish group have been focusing upon the use freezing of sediments in order to assess the feasibility of using these methods to stabilise and raise fragile organic artefacts. The aim was firstly to see if fragile wooden artefacts would be damaged by the shock of freezing. Second, if there was no damage to freeze them in different sediment types (sand and gyttja) to see what effect this had on the process and if there were any significant weight changes. To assess the state of preservation of the wooden artefact before and after freezing, a small ca. 2000 year old, heavily degraded spear shaft was cut into six pieces, where one was used to examine the density (81 kg/m3) of the wood and used as a control sample for scanning electron microscopy. After being weighed liquid nitrogen was poured over the five different setups. As soon as the “smoke” had dissipated they were weighed again. As seen in table 1 only minor differences in the weight were noticed from before and after the freezing treatment.

Table 1. The wood pieces were treated in the five ways seen here and were weighed before and after liquid nitrogen was poured onto them

Wood sample	Weight before (g)	Weight after (g)
Without water	48,75	48,38
With water	337,72	334,26
With gytje (3,5 x 7,5 cm)	184,12	183,27
With sand (4 x 13,5 cm)	414,31	412,61
With sand and water	621,7	620,1

To evaluate the possible damaging effect from the freezing on the artefacts,
SEM microscopy was carried out on the six pieces (Fig. 4).

No damage, collapse of cells, was seen after the freezing treatment. These results show that the weight of the frozen sediment is almost the same as in an unfrozen condition and that the wooden artefacts are not notably damaged from the freezing.

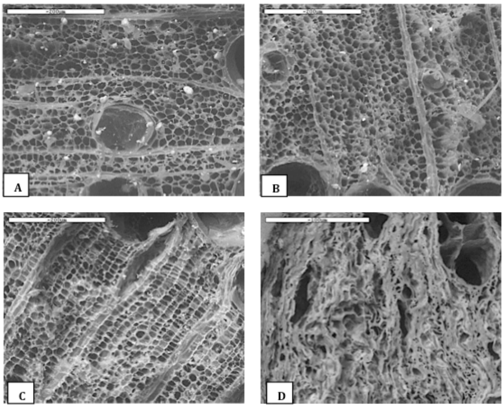

Fig. 4. SEM of the non-frozen wood (A). SEM of the wood covered with gyttja (B). SEM of the wood covered with sand and water (C). SEM of ovendried wood (D). Photos National Museum of Denmark.

3 Conclusions

The research conducted in the WP 5 of the SASMAP project was addressed to development of tools and best practice for the raising of poorly preserved waterlogged organic artefacts, when it is not be possible to preserve them *in situ*. The philosophy of intervention is common to all the materials and techniques tested (innovative or available on the market): artefacts and sediment can be raised as a complete unit without having to be cut into smaller fragments; all are environmentally friendly and they do not damage the artefacts if they are in direct contact with them. Furthermore, all of them will be designed so that excavation can take place in a controlled manner and can be completely secure.

The lifting frame and the sheet of carbon fibre in a plastic bag vacuum are modular techniques useful to lift little or big artefacts; in the case of portion of large objects such as hull remains and log boats, could be better to use sheets of carbon fibre in a plastic bag, because they can bear very large weights without being heavy themselves. Indeed, the shell itself may also act as an effective container for temporary storage and first aid restoration treatments.

The Freezing method could be a good technique, but it requires further investigation to use it underwater. The 3M™ Scotchcast ™ Plus Casting Tape is useful only for small objects, and can be considered a good material for our purposes. Water and Sediment Consolidation System is an innovative method that could open the way for new scenarios in recovering fragile waterlogged artefacts from underwater or land excavation (Table 2).

The SASMAP Project will finish in September 2015, the aim of this paper is to give an overview of the ongoing research. The results achieved in the laboratory and in the field until now demonstrate well the effectiveness of the solutions adopted for recovery of fragile objects from underwater archaeological excavations. The guideline that will be available at the end of the project will be a useful tool for underwater archaeologists and conservators.

Table 2. Tested methods and their application

Tested system	Large artefacts	Small artefacts	Interference with artefacts
Lifting frame	X	X	NO
Sheet of carbon fibre	X	X	NO
3M™ Scotchcast ™		X	NO
Super Absorbent Polymer	Requires more tests	X	NO
Freezing method	Requires more tests	X	NO

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