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LE TOUMELIN: A SUCCESSFUL FERROCEMENT SCHOONER

Antoine E. Naaman [1] and Pierre Brenet [2]

ABSTRACT

Le Toumelin is a 28.5 m long three masts Schooner operating in the French West Indies, particularly around the French Island of Martinique. Its structure, that is, hull, deck, and all bulkheads are entirely made out of ferrocement. Le Toumelin was built in a small shipyard located on the Mediterranean seashore of France, starting in 1975. In 1989, it sailed from Marseillan, France, to the island of Martinique, a journey almost 5000 miles long. It has been in sea water for more than 35 years and has achieved a successful record of service carrying tourists in the Caribbean for more than twenty years. The main objective of this paper is to summarize for the benefits of the reader and future users of ferrocement the main information about Le Toumelin, namely its construction method, details of the materials used for its construction, as well as its maintenance, service history, and milestones of survival.

Keywords: ferrocement, boat building, steel armature, wire mesh, sailing2

1- INTRODUCTION - HISTORY

Le Toumelin is a Schooner currently operating in the French West Indies, particularly around the French Island of Martinique located in the East Caribbean close to Domenica and Ste-Lucia. The main city of Martinique Island is Fort de France, and Le Toumelin anchors in the Trois Ilets (Pointe du Bout), a small holiday resort area located in the Fort de France bay.

A Schooner (sometimes also calledfor its French name) is a type of sailing vessel characterized by the use of fore-and-aft sails on two or more masts. Schooners were first used in the 16th-17th century by the Dutch and were further developed and extensively used in Europe and the Americas for fishing and transportation; they are characterized by their speed, windward ability and maneuverability. Goelette

Le Toumelin is a three masts Schooner having 9 sails with a total surface of 480 m2. What is most particular about it is that its structure, that is hull, deck, and all bulkheads are entirely made out of ferrocement. Ferrocement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh [2, 3, 4, 12]. While numerous boats were built with ferrocement and operated successfully in the past, very few have their service performance in sea water documented. Currently, Le Toumelin functions as a tourist charter vessel with day trips around the island of Martinique or to the other nearby islands. It can carry up to 46 people for day trips with food service facilities, or up to 12 passengers with overnight sleeping accommodations. The crew comprises four to six members. Under the deck are four fully equipped cabins for passengers and one cabin for the crew.

Le Toumelin was built in a small shipyard located in Marseillan, a village close to the shipping harbor of Sète on the Mediterranean seashore of France. In 1989, it sailed from Marseillan to the island of Martinique, a journey almost 5000 miles long. Its ferrocement hull has been in service in sea water for more than 35 years and in the Caribbean for more than twenty years.

1. Professor Emeritus, University of Michigan, Ann Arbor, USA 48105
2. Captain, Le Toumelin, Point du Bout, French Martinique

who, between 1949 and 1952, circumnavigated the globe using a ten-meter long sailboat, named Kurun, alone without any engine or technical assistance. He was the son and grand-son of sailors and had built his own sailboat. At the time, he was the third known sailor to have accomplished this challenge. The story of his journey is written in a book titled Kurun [1] (the name of his sailboat which means thunder in Breton), which inspired the second author to pursue his interest in sailing and lead to the construction of his own 3 masts schooner. Kurun is now a classified historic monument and is located in the museum of Croisic in France.

The photos in Fig. 1 show Le Toumelin from different angles with its full sails on, and without them. There is no need to comment about its beauty, grace and fluidity, which prompted the authors to tell her

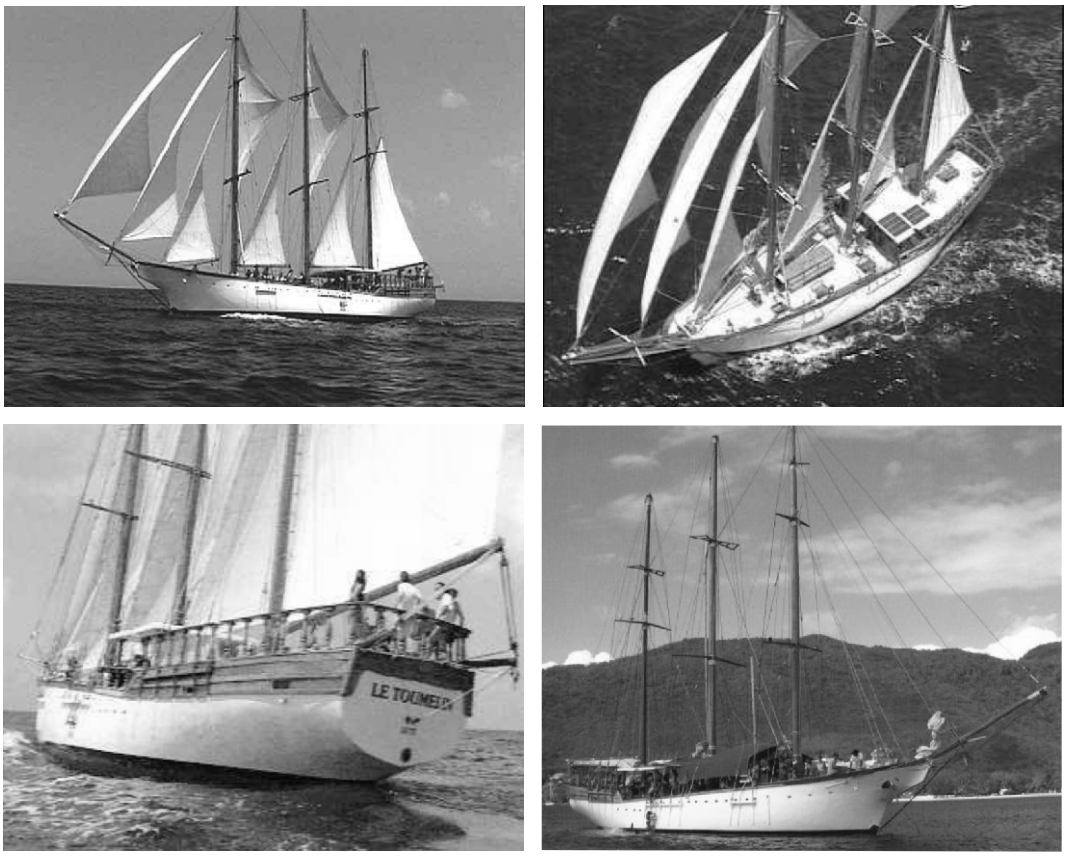


Figure 1-Photos of Le Toumelin at sea with all its sails on, and without them at port

2- OBJECTIVE

The main objective of this paper is to summarize for the benefits of the reader and future users of ferrocement the main information about Le Toumelin. It is observed that the construction of Le Toumelin did not entail the use of any high technology process or equipment; to the contrary, it was carried out by an amateur 4 builder and craftsman, P. Brenet (the second author), following what was at the time available technical recommendations for ferrocement and common sense engineering [5 to 9]. It should be noted, however, that prior to undertaking his project, Captain Brenet had practical training in industrial design, naval architecture, mechanics of materials and naval structural carpentry. He was also a long-standing sailor who had practiced since childhood, and held several French Merchant Marine Certificates including engine room control certificate. Prior to completing Le Toumelin he owned a smaller sailing boat with a steel hull.

3- CHARACTERISTICS

As mentioned above, Le Toumelin was built by the second author, who, from a cement and concrete technical perspective, was an amateur builder, but knew a lot about sailing and naval procedures. So when he decided to design and build his own boat, and given his past experience with different materials, he opted for ferrocement. Following are the main characteristics of Le Toumelin:

-Hull length: 23 m
-Overall length including the bowsprit: 28.5 m
- Beam (i.e., maximum width): 6.3 m
-Draft or distance between waterline and bottom of the hull: 3 m (or load line)
-Weight: 75 metric tons
-Ballast: 23 metric tons

Under deck, it has four cabins each with a sink and toilet facility; there are also two showers; they can accommodate up to 10 passengers for sleeping. There is also one cabin for the crew which could accommodate up to six people. Used as a day charter, Le Toumelin usually receives up to 46 passengers with food service.

The construction plans for the boat were designed by the second author, P. Brenet, following existing examples from French models of similar boats, and were certified by the French Admiralty Department in Marseille, France. As the boat was initially intended to operate as a charter for the Merchant Marine in the Mediterranean sea, the hull building was supervised by the French Marine Authorities of Sète, a nearby port, and certified for sailing upon its completion.

It should be noted that during the period it took to completely finish Le Toumelin on the inside and prepare it to sail long distance, thirteen ferrocement hulls ranging in length from 12 m to 23 m were also built for private customers by the second author who was then the contractor and shipyard owner. 5

4- CONSTRUCTION METHOD

The hull of Le Toumelin was built using what is known as the open mold method of construction [3, 4, 5, 12], a traditional boat building construction technique. In this method, an open mold is constructed using a stiff wood framework, made of a succession of multiple frame sections acting as ribs and stiffeners and simulating the final shape of the hull. Among these framing sections are also some sections especially designed to accommodate future bulkheads. The heavier framing sections are then connected by a lattice of wood strips or ribbands (Fig. 2). Then the reinforcement is added. The heavier framing (which is used to give the shape) is dismountable so that it can be removed and recovered later. The ribbands allow the mesh layers to be stapled to them for proper positioning, until the whole reinforcing system is completed and additional ties are used as needed to secure the various reinforcing meshes together each time a layer is added. The ribbands, spaced at 10 to 15 cm are largely removed before the mortar plastering to make it easier to plaster from the inside to the outside.

The reinforcement of the hull consisted essentially of three main layers, like a sandwich with two outer skins and a skeletal steel core in between. The first skin layer contained four layers of chicken wire mesh stacked on top of each other and regularly stapled to the wood frames and ribbands; it was followed by the core layer of skeletal steel made out of a grid of 8 mm deformed reinforcing bars spaced at about 50 mm center to center; then the third layer, the outer skin, contained four layers of chicken wire mesh.

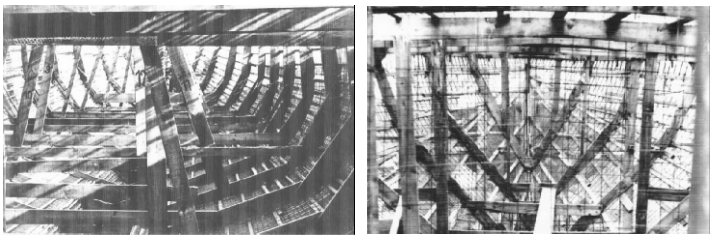


Figure 2-Illustration of the open mold method of construction with successive wood frames used to provide the shape of the hull

For the skeletal core, the vertical bars were placed first and stapled to the wood frames, then the horizontal ones were placed and tied to the vertical bars at every 6 crossing joint. A typical cross section of the ferrocement structure that made the hull is shown in Fig. 3. The thickness of the hull is generally around 28 mm with a range from 26 to 31 mm. The skeletal core bars were of the "Rumi type" (French made) with an X-like square cross section, 8 mm to each side and a yield strength close to 600 MPa. The reinforcement prior to adding the mesh layers for the outer skin is illustrated in Fig. 4.

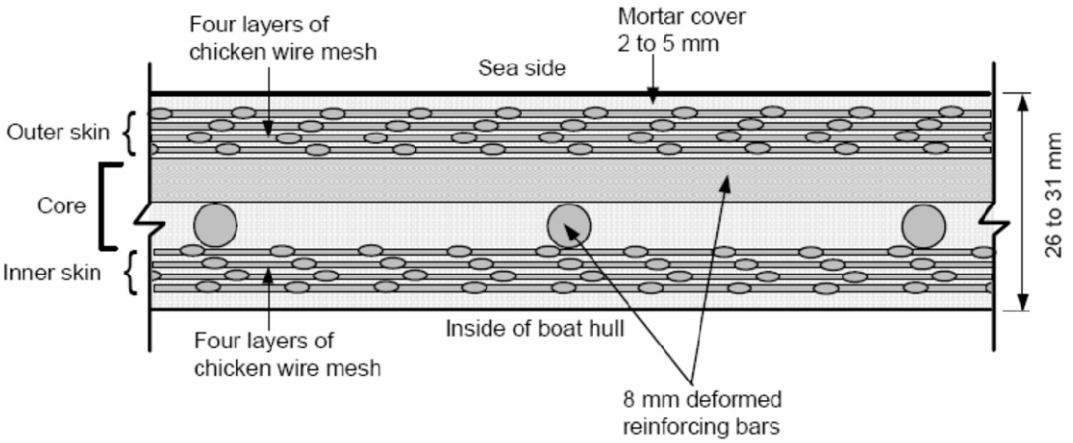


Figure 3-Typical cross section of the hull wall showing the different layers of reinforcement

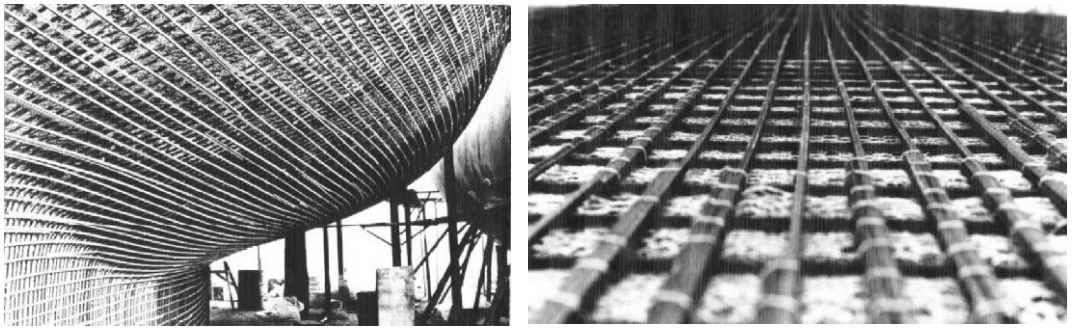


Figure 4-Photos showing the first two layers of reinforcement (inner skin and skeletal reinforcement) prior to adding the outer skin made with four layers of chicken wire mesh

While many ties were used to secure the various layers of reinforcement during placing and construction, once the whole reinforcement of the hull was completed, wire ties were applied at every cross section of the skeletal grid through the entire depth of the reinforcement thus binding the entire reinforcement together. It is estimated that 400000 such ties were used over the 7 entire surface of the structure. Particular care was taken to make sure that tie ends were buried inside the reinforcing skeleton and did not protrude from the surface.

In addition to the above a large number of L shaped pins, with 50 mm for one leg and 200 mm for the other leg, made from the same reinforcing bars as the skeletal steel, were attached at the proper locations to provide the future connections or joints to the other elements of the structure such as bulkheads, frames, floor stiffeners, and cross beams. The leg with 200 mm was attached to the skeletal bars while the leg with 50 mm protruded from the shell.

For all elements other than the hull, such as bulkheads, cross-beams, and floor stiffeners, the

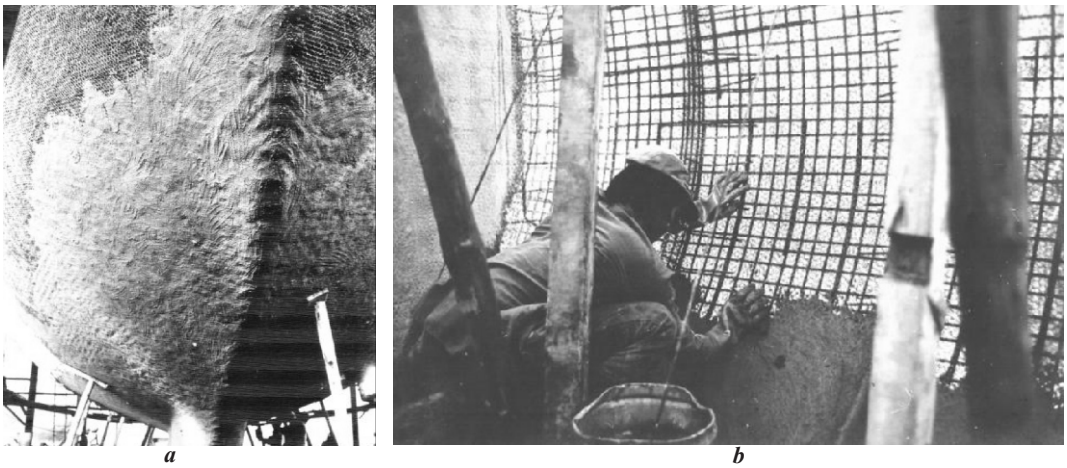
ferrocement composite used the same sandwich construction as for the hull; however, each skin contained 3 layers of wire mesh instead of 4, and the skeletal steel had an 80 mm grid spacing. These elements were meant to be less rigid than the hull in order to provide some flexibility in case of large deformation.

Six bulkheads provided the lateral rigidity of the structure. Each acted as frame as well as a floor beam for both the deck and the bottom hull. Additional bottom floor beams to reinforce the hull between buttresses were built at 80 cm spacing, except for the section of the engine room where the spacing was 40 cm. Moreover, where appropriate, specific reinforcement was added in the bulkheads to prepare the locations receiving the masts.

The thickness of the total reinforcement (that is, the sandwich of wire mesh and skeletal steel grid) for the hull was about 24 mm while for the remaining elements such as bulkheads and deck, it varied from 18 to 22 mm. When mortar was added, the thickness of the hull varied from about 26 to 31 mm, the lower values occurring in areas where the mesh layers were strongly compacted.

After the reinforcement was completed, plastering of the mortar was carried out in three main steps, each separated by a period of time to allow proper curing at 100% relative humidity (using a simple vaporizer while the structure is covered by plastic sheets), and strengthening of the mortar matrix. The bulkheads were plastered first, then the hull, and finally the deck leading to a monolithic structure.

When there was interruption of mortar application, a latex-based bonding agent (Prolax) was used prior to application of a new mortar. A typical photo illustrating the mortar application is shown in Fig. 5a. Note that for plastering the hull, the wood ribbands were first removed, and the mortar was applied from inside the hull, forcing it through the reinforcement system toward the outside; it was then finished from both sides (Fig.5b). This essentially required a two-person team. In order to create a stronger joint and facilitate the connection with the deck, a band of about 100 mm at the periphery of the deck was plastered simultaneously with the hull.



a *b*

Figure 5-Typical mortar plastering of the hull: a. exterior surface prior to finishing. b. plastering from inside

Once the mortar had reached its strength, the exterior surface of the hull was ground and sanded to smoothen it and prepare it for the final coatings. This task was extensive, rather time consuming, but also allowed to check the surface for air pockets or other irregularities and repair them using a rich mortar and the latex-based bonding agent (Prolax).

In order to apply the mortar of the deck, a formwork of plywood boards was used and plastering was carried out from the exterior.

Figure 6-Photos of the finished hull after epoxy coating and polyurethane painting

Upon satisfactory final inspection, five films of epoxy coating (liquefied enough to facilitate penetration) were applied to the hull at intervals, each allowing full curing of the epoxy, followed by three coats of polyurethane paint for the final finish. The photos of Figs. 6 illustrate the quality and glossy smoothness of the finished hull. It is estimated that the epoxy layers and coatings added about 1.5 mm of protection to the outer cover, and allowed perfect water tightness.

5- MATERIALS USED

The reinforcing mesh was a galvanized chicken wire mesh with a mesh opening of about 19 mm and a wire diameter of 1 mm. A total of 4400 m2 of wire mesh was used for the project. The deformed reinforcing bars were of the type Rumi Tors (French bars of square-like X section) of 8 mm and came in lengths of 12 m each. Their tensile yield strength was about 600 MPa. A total of 18000 linear meters was used.

The mortar matrix consisted of cement, sand and water in the following proportions: 1 part cement, two parts sand and about 0.4 to 0.5 part water. The cement was a typical Type V cement produced by Lafarge, for sea water environment. The sand originated from the Drome river, with a grain size ranging from 90 microns to 3 mm. Particular attention was placed to make sure that the sand had a good distribution of particle sizes averaging 1.5 mm (2 parts by weight), 900 microns (1 part), 400 microns (1 part), 200 microns (1 part) and 90 microns (1 part). The compressive strength of the mortar was about 35 MPa at 7 hours and was expected to reach a design strength of about 75 MPa. When finishing the outside of the hull, only 200 and 90 microns average sands were used.

6- Hauling, Cleaning, Inspection History and Milestones of Survival

Upon completion, the ferrocement hull stayed in sea water from 1975 to 1984 during which the boat interior was worked on at leisure. Its hull was hauled in 1984, cleaned and appeared at the time to be in excellent condition. Between 1984 and 1989, Le Toumelin was finished with its full mechanical (a diesel engine of 260 horse power was added) and navigation equipment and readied for use in high seas. In 1989, prior to crossing the Atlantic, Le Toumelin was again hauled and its hull cleaned, fully inspected, and given a clean bill of health. Typical photos illustrating the completed interior of the boat are shown in Fig. 6.

Since 1990, the boat was hauled regularly each one or two years for cleaning and inspection. Three events of interest should be noted because they illustrate the strength and qualities of the ferrocement composite and hull structure.

In 1993, while taking off the masts for maintenance, the cable of the lifting crane broke and the cable end block (about 200 kg) fell down from about 12 meters in height directly onto the deck. While the impact was strongly felt, it did not produce a hole in the deck but extensive cracking around the impacted zone. Later the cracked mortar was removed, the bars realigned, the chicken wire mesh replaced, the area cleaned and a new mortar applied; this was a very cost effective repair.

Figure 6-Photos illustrating the interior quarters of Le Toumelin finished with a rich African mahogany wood (top: library and map room, cabin, stairs; bottom: sleeping cabin, dining area)

In 1996, the hull was again hauled and sand blasted for a full inspection. Two sites showed slight discoloration on the inside due to corrosion. These were the zone where the chain of the anchor penetrated the hull, and another zone at the toilet intake of sea water, each about one square meter in area. These were repaired by removing the mortar, cutting off the corroded portions of bars, welding replacement bars to the remaining ones, adding the layers of wire mesh for both the inner and outer skins, tying the whole to the existing skeletal steel, toweling a rich mortar containing an adhesive agent, and finishing with the epoxy coatings.

In 2004, a fire broke in the engine room due to a gas-oil transfer mistake. Fortunately the fire, while lasting 15 to 20 minutes, did not spread; it was then contained and the hull did not sustain any short or long term damage.

These milestones confirm several known advantages of ferrocement such ductility, resiliency, and impact and fire resistance.

The various photos in Fig. 6 illustrate the interior of Le Toumelin where rich African Mahogany wood is used. Fig. 7 provides a view of the deck with details of the helm and typical mast connection.

Figure 7-Typical photos of the helm, mast connection, and top deck

7- CONCLUDING REMARKS

In short Le Toumelin has been in sea water for more than 35 years and has been sailing in the East Caribbean sea for more than twenty years. At time of this writing, its ferrocement structure is still in very good condition. Given what we know today about advanced materials that could be used in future ferrocement structures, such as ultra-high performance fiber reinforced concrete and very high strength steel wires or textiles [10, 11], the success story of Le Toumelin is very encouraging. It is hoped indeed that it will inspire more amateur as well as professional boat builders to consider ferrocement as a viable and competitive alternative material in future projects.

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