Transactions on the Built Environment vol 65, © 2003 WIT Press, www.witpress.com, ISSN 1743-3509

Measuring the Vasa

J. Jacobson
The Vasa Museum, Sweden

Abstract

In the middle of the 1990's the thought of a more accurate measuring system for the Vasa began to take shape. We knew that the ship moved but we did not know exactly where and by how much. If one does not know how the hull moves, it is very difficult to calculate the best counter-measures. Since we wanted to monitor the movements of the ship over time, we arrived at the conclusion that a geodetic system would best serve our needs. Together with the Royal Institute of Technology in Stockholm we started to plan for a geodetic measuring system in the museum. Old boreholes were used to attach 350 reflective targets to the hull. A total station was bought and with this station we can get a very high level of accuracy, down to a few tenths of a millimetre. The plan is to measure the ship four times a year. We have now measured the Vasa six times and the results so far indicate movements in several areas of the ship. The clearest trend, though small, is a downward motion. With the data so far collected, the rate of movement is around 1 mm a year.

We are now extending the system to the inside of the ship to cover the upper and lower gun decks. In the autumn of 2002 we will do a laser scan of the Vasa. One benefit of the scanning will be a digital 3D-model of the Vasa, which will make it possible to visualise the result from our geodetic measurements and simulate what will happen in the future if we do not act.

1 The ship

The Vasa sank on her maiden voyage on the 10th of August 1628. She sailed about a mile on a fine day with a light wind. Then a slightly stronger gust filled the sails, causing the ship to capsize and sink in the middle of Stockholm's harbour. The Vasa is in many ways a unique example of a historic ship. Apart from being the only 17th century man of war in a museum, the principles for her preservation are different from many other ships. Even today, our knowledge about the design of the Vasa is limited and we do not know all the facts about the disaster. 17th century shipbuilders did not produce construction drawings or calculations of stability. We do know that the Vasa has a displacement of 1200 tons, she is 69 meters long (with the bowsprit), has a beam of 11.3 meters and is 52.2 meters tall.

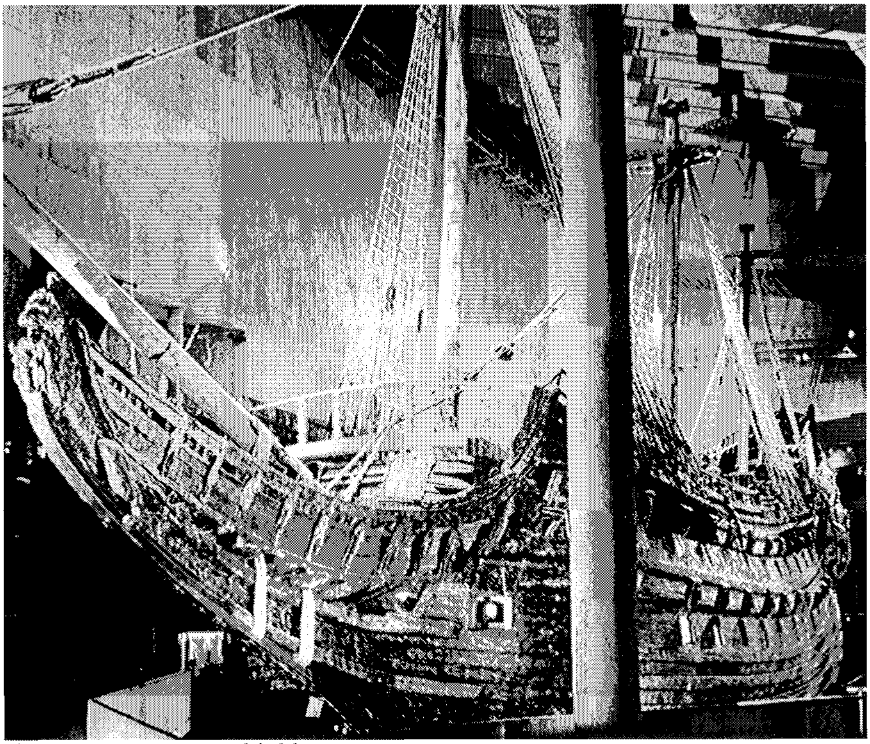

Photo: Hans Hammarskiöld

2 Salvaging the Vasa

In 1956, Anders Franzén found the Vasa after searching for five years. A few days later the diver Per Edvin Fälting confirmed the find. After much discussion, the Vasa was salvaged using conventional methods. Heavy steel cables were laid under the hull and attached to submergible pontoons, which were gradually able to lift the hull. The actual salvage began in 1959 and on the 24th of April in 1961, after 333 years on the seabed, the Vasa broke the surface. After being salvaged, the Vasa spent just a short time in the open, first afloat and then dry-docked on the island of Beckholmen. During this very intensive period, work was done on the ship on many different levels.

Transactions on the Built Environment vol 65, © 2003 WIT Press, www.witpress.com, ISSN 1743-3509

The archaeologists catalogued thousands of finds in just five months, digging through mud and silt aboard the Vasa. They worked through the summer in rubber suits, as the ship was sprayed with water to avoid shrinkage and damage to her timbers.

When the ship was salvaged, there was concern about the strength of the hull. The ballast (about 120 tons of stone) was still in the hold and large amounts of mud and muck remained aboard. Most of the iron fastenings were corroded, so the ship depended on her wooden treenails to hold the hull together. The divers managed to strengthen the hull considerably. By replacing bolts, and nailing boards and planks over the most damaged sections of the ship. This work was intensified when the Vasa was dry-docked. The preservation of the Vasa had begun. How do you preserve 1,000 tons of oak, 14,000 wooden components, 500 figurines and thousands of small objects?

The method adopted was to spray the hull with a mixture of polyethylene glycol and water. Most of the objects were immersed in preheated polyethylene glycol. At the same time the conservation department kept developing the method. The general idea was to displace the water in the wood to prevent shrinkage and splitting. The spraying of the hull continued for 17 years.

At the same time as work was done on the ship and her artefacts, the first museum (Wasavarvet) was planned and built. The ship, on her floating platform surrounded by an aluminium building, was towed to the museum site in 1962, less than a year after the salvage. The building around the ship was there to enable the conservation process, so the spectators shared the same damp conditions as the ship. Exhibitions and other facilities were placed outside the ship's building. The old museum was not perfect at all, but in many ways preservation came first, and the public second.

So, in just a few years, a complete 17th century ship was salvaged, a method for her conservation thought out, the process of strengthening the hull and replacing loose objects was started and the museum had opened.

3 The new museum

In 1990 the new Vasa Museum opened to the public. In many ways it is a fantastic place. The architecture is exciting, you can see the ship from many different angles in the large ship's hall, and there is a nice restaurant and an excellent museum shop. You can even entertain your guests here at night, dining beside the ship or organise a conference or a business meeting.

The new museum is a bit more complicated when it comes to preservation. Many people obviously thought that the ship was more or less a finished product by 1990, maintenance would be the only task needed to be carried out in the future. Facilities for working seriously with the ship are minimal in the new museum. The workshop is fine for building exhibitions, but has no climate control for working with ship's timbers. There is no conservation lab, very little storage space for artefacts and working in the ship's hall is difficult once the museum is open for the day.

Transactions on the Built Environment vol 65, © 2003 WIT Press, www.witpress.com, ISSN 1743-3509

In fact, the large ship's hall is one gigantic display area. The problem is that one usually does not let visitors into a museum display case. It is difficult to maintain a perfect climate. The numbers of visitors and the size of the place make it difficult to avoid different climate zones. It is also difficult to work on the ship during opening hours, without exposing the public to noise and risks.

Surveying the ship at the old museum was difficult. The Vasa was on a floating platform, she was being sprayed with polyethylene glycol and the restoration work was in progress. As the ship kept changing it was hard to establish accurate plans or a base to work from.

Even in the new museum, with the restoration work more or less completed, a very large ship like the Vasa is difficult to monitor by hand or eye only. It is also hard to transmit observations from shipwrights or conservationists into facts and figures, but in order to make decisions for future planning these facts are necessary.

4 The geodetic system

During the 1990's we realised we had to find new ways of documenting the Vasa. There are obvious disadvantages with documenting a large ship using only measuring-tape. This is not the most accurate method, and it is difficult to measure anything except the inside of ship.

When we started looking for a system for monitoring the stability of the hull, we also wanted something that would interest other museum staff, scientists, the media and the public.

Another important consideration was finding a system that would survive for a long time. We realised that a highly accurate system would be expensive, so we did not want to have to change the system after only a few years.

The idea for our system came from England, when a company was due to build near the "Cutty Sark" in Greenwich. The building company was concerned about the impact on the ship. They established a surveying system to control if, and then by how much, the ship was moving during their blasting. They used a total station for the job and targets where placed on the Cutty Sark and in the dry dock, in short it was a geodetic system.

After discussing various solutions with the Department of Geodesy and Photogrammetry at the Royal Institute of Technology in Stockholm, we decided to use a geodetic system for the Vasa as well. The institute would design the system for the Vasa Museum. Dr. Milan Horemuz from the Department of Geodesy and Photogrammetry was brought in as a consultant and project manager.

There were several reasons for choosing a geodetic system. It is highly accurate. We would be able to detect movements in the hull that are below a millimetre. We would be able to target a large number of points on the ship, creating a good overall picture. It would be flexible, in the future we could extend the system to cover the inside of the ship and also create further target points in sensitive areas. On the other hand, the system would be expensive and

Transactions on the Built Environment vol 65, © 2003 WIT Press, www.witpress.com, ISSN 1743-3509

we would need to rely on outside experts for design and maintenance, even if we planned to operate the system ourselves.

A geodetic system will measure distances and angles in three dimensions, X, Y and Z, by using a total station. The results, in the form of co-ordinates, will define the exact positions of chosen target points on the ship. When measuring the same points again at another time, any differences between the co-ordinates will be movements in the ship at those points. By monitoring a large number of points and by doing a number of surveys (or epochs), you will end up with a clear picture of any deformations in the hull of the Vasa.

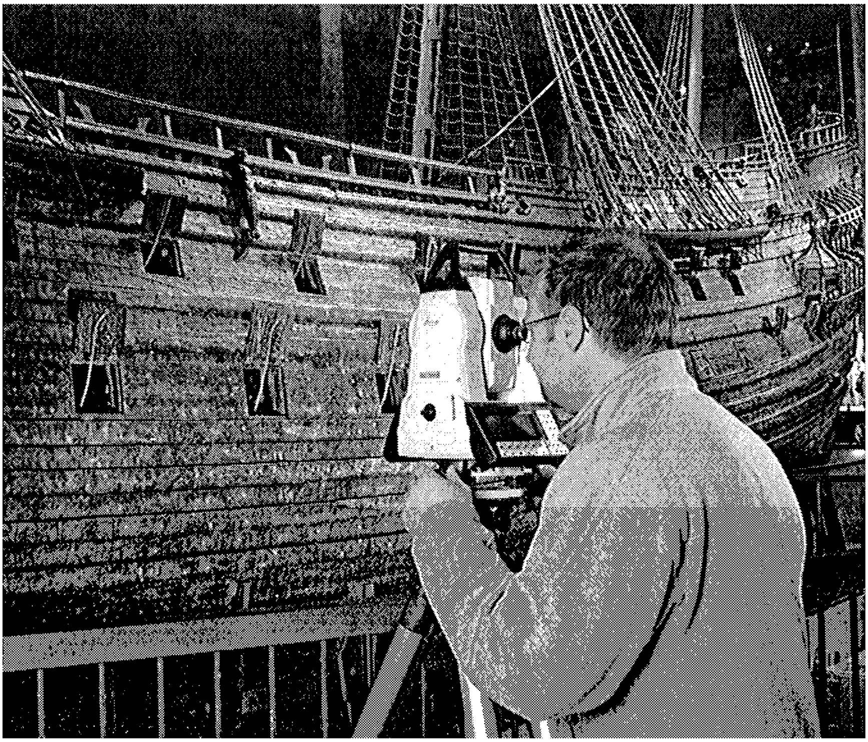

Photo: Stefan Evensen, SSHM

Dr Milan Horemuz started with designing the control network of prisms around the ship. The control network is vital to establish the exact positions of the total station. The station does not have to be placed in exactly the same place for every survey, but will find its positions with the help of the control network.

For each position where the station is placed, the control network is used for the station to position itself. It is one of two important tasks of the network. When the station is positioned, it is time to get the steering-file from the station's memory card. When the file is loaded the station knows which prisms in the control network and which targets on the ship will be measured from that position. When positioned, the station also knows the estimated position for both the prisms and the targets. The total station is equipped with a servo and finds the rough position of the prisms and the targets by itself. The operator has only to do the final adjustments and press "All" to record the co-ordinates on to the station's memory card. The network is also vital as a reference. We need "stable" positions as a reference to the targets on the ship.

While Dr. Horemuz designed the control network, we were busy fastening the targets to the ship. The targets are made up of reflective tape, with a cross in the middle and look like targets for shooting, but much smaller. The tape is glued on to a round piece of plexiglas that is fastened to the ship. In total, we put up close to 350 targets on the ship, cradle and pontoon. We did not want to bore new holes in the ship so we fastened the targets on the hull by using old boreholes, holes that originally were made to check the penetration of the polyethylene glycol in the wood during conservation.

All targets are measured twice and from two positions at least, which makes the system even more accurate. The measurements are saved on the total station's memory card and are then processed by specially designed software on a PC.

By moving around the ship and establishing the total station in 50 different positions, two people are able to measure the 350 targets on the ship in a week and a half, creating an epoch, which in total consists of about 2,000 measurements. In reality though, there are five people who take turns behind the station. To measure a whole epoch with only two people puts too much strain on them, the eyes have a hard time to concentrate during such a long period of time. One person will then have to spend a few days computing the measurements and compare the results with earlier epochs.

Even if we see the geodetic system as a major component for the future preservation of the Vasa, it is by no means a finished product yet.

During the summer of 2002 we extended the system to include the inside of the ship, beginning with the upper and lower gun decks. On these decks we use prisms instead of the reflective targets that are used on the hull. The main reason behind this decision is a higher degree of accuracy. There is also another major advantage with prisms. The total station has a built in function, Automatic Target Recognition (ATR). This enables the station to automatically find the centre of the prism. We have only to aim the prisms towards the station and press "auto". Since the rough position is registered in the station memory card and it can automatically find the centre of a prism, it measures whole sets by itself.

Since we were planning to execute the geodetic measurements four times a year and in principal forever, it was important that the system was as automated as we could afford. This meant that we bought a total station with a high level of accuracy, which was programmed to automatically find a defined number of targets on the ship from each position. The operator only needs to tell the station in what position in the ships hall it is standing and to do the final adjustments on each target.

To measure the Vasa out in the hall while the museum is open involve several problems. The two major problems are the large number of visitors in a limited space and that the ship's hall is relatively dark, since the ship demands it.

Transactions on the Built Environment vol 65, © 2003 WIT Press, www.witpress.com, ISSN 1743-3509

Planning solved the problem with the visitors. We can not limit our measuring to when the museum is closed, each epoch would then take a month or so. We took the decision not to measure during high season, from the middle of May until the end of September. We try to measure once in the beginning of May and once in the end of September, it gives us an indication the effect of the massive amount of visitors during a 4 months period has on the ship. The "winter measurements" we try to fit in late November and in the early February. So far we have found no problems with positioning the measurements this way.

For the first couple of epochs the light was a rather serious problem. When measuring you need light on the targets to be able to do the final adjustments. It was a tricky problem to solve. We tried different solution and in the end we built a "light carriage" on which three spotlights, run by two batteries, were mounted. It works perfectly and at the moment it seems to be the final solution to the problem.

Another issue came up when we were presenting the result of the measurements. The results were presented as a very long list consisting only of X, Y and Z values. The list contains over 2,000 sets of values and to compare the different epochs for movements would be almost impossible.

We soon realised we had to "market" the geodetic measurements. It was important to get our colleagues to realise the full potential and value of the system. A key element is to make them understand the results we produced and what it represents.

During the winter of 2001–2002 Dr. Milan Horemuz worked on a presentation of the results which would be in a more comprehensible manner. He managed to work out a way to present the difference between the epochs in a bar chart. This is a much better way to present the movements in the hull but it is still not as good as we want it. We have now started the work with a digital visualisation of the results. Hopefully we will have a very good presentation of the movements in the hull during 2003.

Results

We have now measured the Vasa six times and the results so far indicate movements in several areas of the ship, though none are alarming. The ship is made of wood and wood is a living material, it reacts with its environment. We have one rather clear trend – a downward motion. As of now the rate of movement is around 1 mm a year.

The reason for installing the system was not because we had specific concerns about movements in the hull. We did not expect to find any alarming movements, as the ship and the support systems for the ship; bolts, cradle, deck beam supports, stern and rig wires are maintained as well as they can be. However, the day will come when these systems will have to be improved or renewed. Then we will have a set of measurements and a geodetic system that will ensure that the existing hull form can be kept for the future.

Transactions on the Built Environment vol 65, © 2003 WIT Press, www.witpress.com, ISSN 1743-3509

The future

During the autumn of 2002 we will scan the ship with a Callidus laser scanner. There are several reasons for this. One benefit of the scanning will be a digital 3D-model of the Vasa. This makes it possible to visualise the result from our geodetic measurements and simulate what will happen in the future.

By scanning the ship we will also get accurate CAD-drawings and be able to link climate control, geodetic surveying and other systems.

With the 3D-model as a base, we aim to create a GIS-database of the ship and all its elements. A GIS-database will work as a tool for future documentation of the Vasa and be very useful in recording the restoration and conservation.

The documentation of the 17^{th} century warship Vasa has come a long way in just a few years. Both the geodetic system and the laser scanning are necessary steps to continue ensuring that our documentation has a high quality and continued public interest. Our work would not have been possible without all the excellent documentation that has been carried out before us by staff at the Vasa museum and outside researchers.