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AWST-11/Jaeger Lecture

"MOSE" - A Monumental Construction for the Protection of the Venetian Lagoon

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Abstract

In order to protect the Venetian Lagoon from flood, the Venetian Water Authorities approved the **MOSE** project -"**MO**dulo **S**perimentale **E**lectrromeccanico" - for construction. The construction provides for the harbour entrance to be closed in case of flood risk by means of flexible barriers on the seabed.
The system has been designed to withstand a water level difference of 2m between lagoon and sea. As the water level will rise by 2m due to expected climate changes, it is assumed that the system will protect the Venetian Lagoon from flooding in the next 100 years. The construction costs of this gigantic system are approx. 10 billion €. The barriers are planned to be put into operation in June 2012.

This article first describes the functional principle of the system, then explains in detail the welding of the support unit and the hinges of the barrier section which are considered as the core of the system

1. Introduction

During the last centuries, the Venetian Lagoon was flooded with increasing frequency. Between 1950 and 2000, the number of spring tides with min. 110m above sea level increased from 10 to more than 80. These spring tides do not only endanger the economic interests of Venice but also its inestimable cultural possessions. Over time, the entire structure of buildings will be destroyed, and the future of this historically unique lagoon city which UNESCO declared as World Heritage Site in 1987 is endangered. With these issues in mind, first contemplations were started in the beginning of the 1970ies how this problem could be solved. After various feasibility studies, the decision was made in 2003 to provide flexible flood protection barriers, and the Ministry of Infrastructure/the Venetian Water Authorities approved its construction.
The concept intends to close all three harbour entrances (Lido, Malamocco and Chioggia, see picture 1) which connect the lagoon with the sea in case of flood danger by means of flexible barriers located on the seabed.

Moreover, each harbour entrance is provided with a long wave breaker which shall reduce the power of the waves; picture 2 shows the wave breaker of Malamocco with a length of approx. 1300m

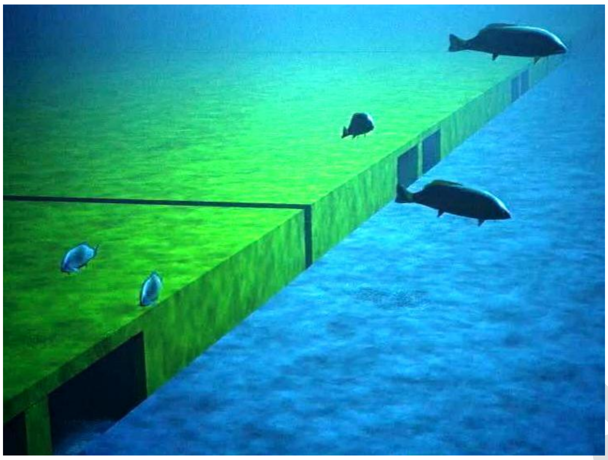
Picture 1. Harbour entrances into the Venetian Lagoon

Picture 2: Malamocco harbour entrance with wave breaker

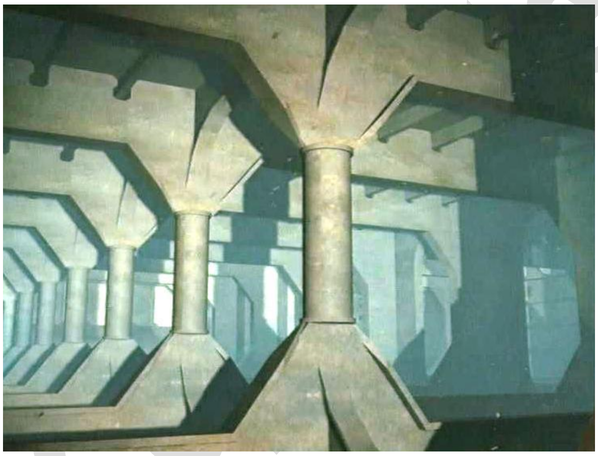
The construction time of this monumental construction is 8 to 9 years. According to the initial plans, the system was intended to be put into operation in summer 2011. In the meantime, a delay of one year is assumed. There are also changes with regard to the planned costs. The initially calculated amount of 4.5 billion € is now forecast to exceed 7 billion €.

2. Functional Principle of the Water Protection System

Picture 3 shows the full view of this underwater system. Modular structures are arranged below the barriers which will keep the steel barriers stable even if a maximum load of water is acting on the barriers. This sub-construction also allows for the disassembly of barrier parts for maintenance which must be accomplished every 4 years. Each individual section is 18m to 21m high, 3.6m to 5m thick and 20m wide.



Picture 3a: Flexible steel barrier on the base



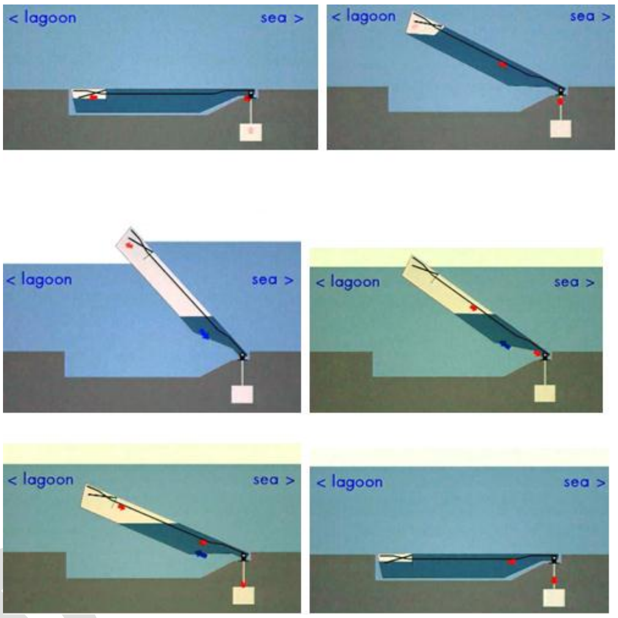
Picture 3b: Modular structures under water

The following protection barriers are provided:

1. Chioggia entrance with 18 tide gates;
2. Malamocco entrance with 19 tide gates;
3. Lido entrance; as this lagoon is the biggest one, two barriers are necessary, i.e. one system with 21 tide gates and one system with 20 tide gates.

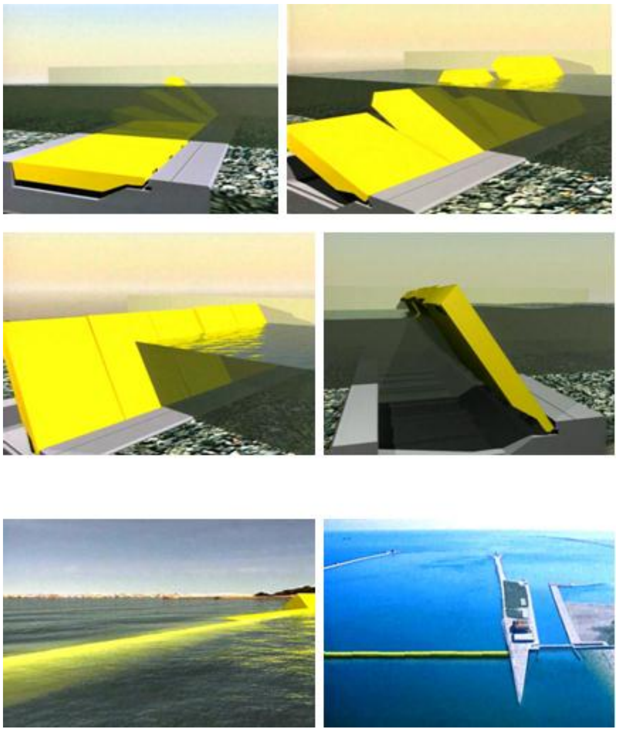
The gates are made of offshore steel S355K2G3 and mounted to the base with two hinges each.

As shown on picture 4, the gates are charged with air, as required. Thus, water is displaced outwards. The hinged barriers are pressed upwards until they reach the water surface thus forming a closed and relatively tight wall at each harbour entrance (picture 5). The distance between each section is max. 3cm.



Picture 4: Principle of operation of the tide gates

The system has been designed to withstand a water level difference of 2 m between lagoon and sea. As the water level will rise by 2m due to expected climate changes, it is assumed that the gigantic system will protect the Venetian Lagoon from flooding in the next 100 years.

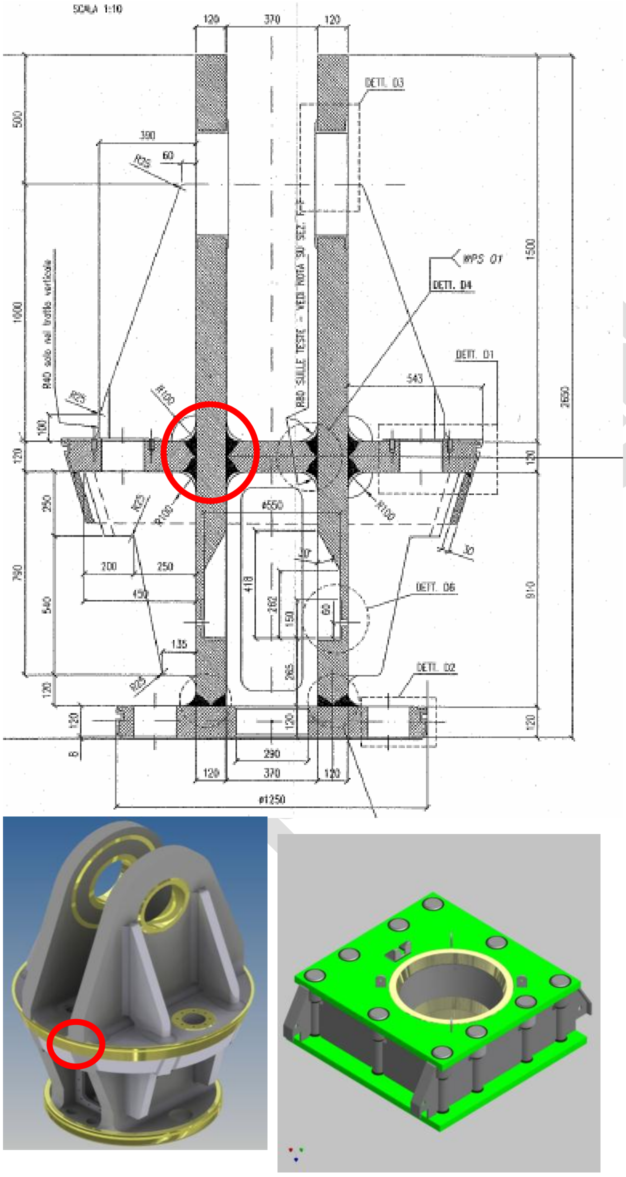


Picture 5: Construction of the protective wall

While the production of the barrier elements which follows the sectional construction used in the ship building industry is quite an easy task, the solutions for fixing units which must bear huge loads must be very well contemplated.

3. Design and Evaluation of Welded Joints on Supporting Devices and/or Hinges

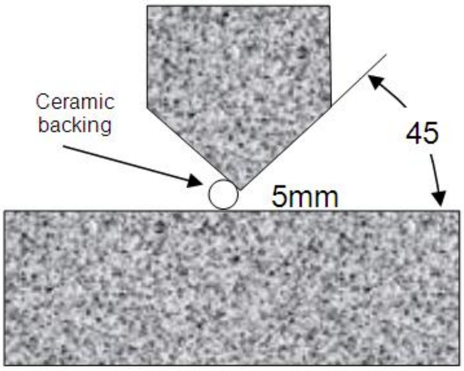
Due to its plate thickness of 120mm on the one hand and due to restricted accessibility on the other hand, the construction places high demands on welding (see picture 6.)



Picture 6: Fixing elements

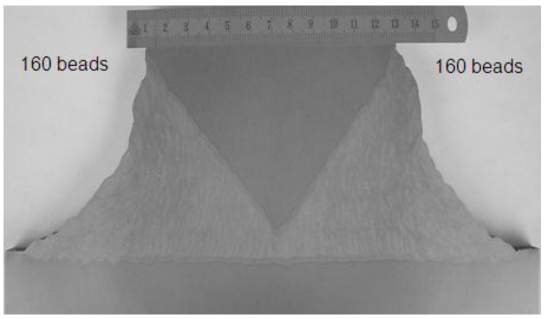
Therefore, the decision was made in favour of the MAG technology with cored filler wires, and welding should be accomplished with suitable robots. For the impeccable seam root coverage of DHV welds (fillet welds), the root was designed on ceramic backing. Due to its restartability and taking into account the requirements with regard to the mechanical quality values, a seamless metal powder welding wire with a diameter of 1.4mm was used. Picture 7 shows in detail the seam preparation and the welding parameters.

Metal cored wire	MF 710 M	Welding method	MAG-M
Size	1,4 mm	Current	220 - 260 A
Shielding gas	82% Ar + 18% CO_2	Voltage	24 - 27 V
Stickout	15-20 mm	Welding speed	33 – 35 cm/min
Base material	S355K2G3	Heat input	9,6 – 12 kj/cm
Wall thickness	120 mm	Welding position	PA - PB
Welding preparation	Symm. DVH 45	Preheating	70 ^{0}C
Gap	5mm on Ceramic	Welding temperature	100 ^{0}C



Picture 7: Seam preparation and welding parameters of the suitability test

As can be seen on the macro section shown in picture 8, the seams are absolutely impeccable despite the huge wall thickness. Due to the reliable wetting of the filler wire arc, there is no lack of fusion which is very common for MAG solid wires under difficult conditions.

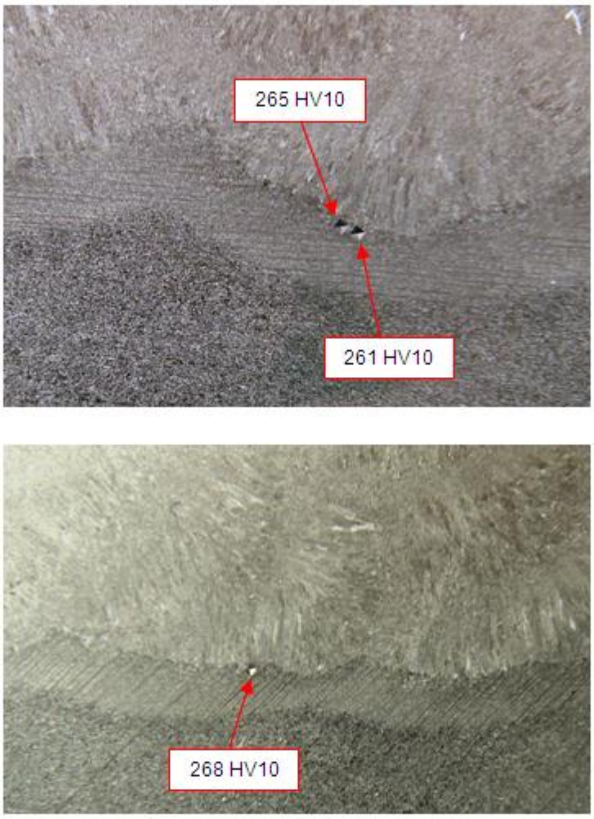


Picture 8: Macro section of DHV seam with full connection

Hardness profiles were determined first for the evaluation of the seams. While hardness did not exceed HV10 in GW 172 (see below), the coarse grain zone showed peak values of up to 268 HV10, which is, however, completely uncritical for this material.

GW			SG			GW		
152	155	172	201	191	181	166	150	146

HV in the coarse grain zone	265	268	261	265



Picture 9: Hardness values in the coarse grain zone

In order to illustrate the coarse grain zone hardness, the HV10 indents are shown on picture 9 in the macro range. Despite the huge plate thickness of 120mm and the relatively low preheating temperature of 70°C, the coarse grain zone is relatively narrow. It can be assumed that the measurement reliably captured the coarse grain zone and that the determined values reflect the highest possible level.

Table 1: Strength properties of DHV seams

Round Bar Specimen	Probe 1	Probe 2
Tensile strength (N/mm^2)	573	586
Yield Strength (N/mm^2)	505	516
Elongation (%)	26	26

The strength properties listed in table 1 exceed the requirements, so that there are still huge reserves. The specimens are round tensile specimens which were prepared along the seam.

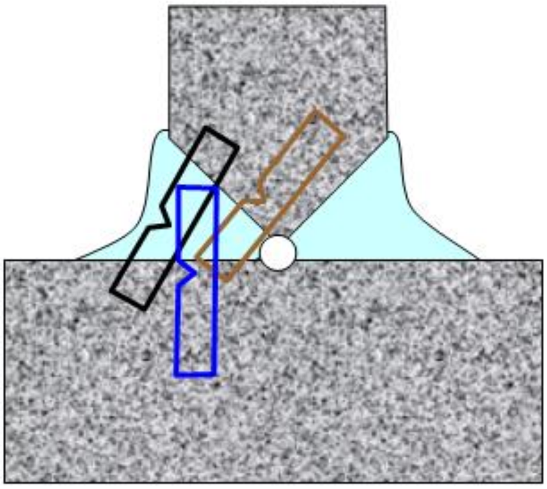


Table 2. Toughness properties of DHV seams

Impact Energy (J) at - 20 ^{0}C				
Weld Centre	**150**	**174**	**190**	**171**
HAZ Flange	**169**	**165**	**153**	**162**
HAZ Web	**162**	**189**	**140**	**164**

On request of the user, the toughness requirements were determined according to the specimen position describe in picture 10 at -20°C. All average values from 3 notched specimens are above 160J with adequate regularity. Despite the differences between the tested sections (the centre of the seam, HAZ belt und HAZ web) the slightly better level of the seam centre corresponds to the regularity of hardness, as expected, whereas it is approx. 60 HV10 below the HAZ.

5. Prospect / Summary

The worldwide unique MOSE project is at the centre of public interest. The successful completion of the project is not only expected by system operators and politicians but also very much by the residents of the Venetian Lagoon because they want their extraordinary city and their inestimable historic and natural possessions to be protected. Therefore, the selected MAG welding technology with filler wire electrodes is very important because, due to its operational reliability with regard to seam quality, it will contribute to the successful completion of the MOSE project with utmost quality in any respect.

The Jaeger Lecture

Prof. Jaeger (Netherlands)

During his presidency of the IIW, the Union of International Technical Associations was set up under the auspices of UNESCO and with the participation of various international bodies, which, like the IIW, became its founder members. This initiative was strongly supported by Hans Jaeger who, like the other founders of the IIW, was a fervent believer in international cooperation. His support of the UITA was warmly welcomed by that organization, which appointed him Vice President and subsequently President, a post which he held for six years
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*The **Jaeger Lecture** is the introductory Lecture of any IIW Regional Congress.*

Professor Jaeger was a naval architect who had worked for 20 years in the shipbuilding industry in Belgium and the Netherlands before becoming Professor of shipbuilding in the University of Delft in 1946, a chair which he held until his retirement in 1969. He was highly successful in building up his department and installing in it the most modern equipment, including a test tank and fatigue testing equipment.

On the foundation of the IIW, he was appointed a Vice-President and was also, for many years, Chairman of Commission II "Arc welding".

Professor Jaeger was elected President of IIW (1951 to 1954) and Treasurer, after which he remained on the Executive Council, until his death in 1984 with the title of Founder Vice-President.