June 5-8, 2018
Rome, Italy

International Conference on Deep Foundations and Ground Improvement

Urbanization and Infrastructure Development: Future Challenges

www.dfi-effc2018.org

TTMJ – THE NEW SYSTEM FOR SLURRY (DIAPHRAGM) WALL JOINTS

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ABSTRACT

TTMJ is the acronym for the Diaphragm Wall Tension Track Milled Joint currently in development as part of the European Union's innovative and far-reaching Horizon 2020 initiative (FTI Pilot-2015-1 720579). The TTMJ system is protected by patent in Europe and the USA and is currently under development by a consortium comprising TREVI SpA (Italy), Arup (Netherlands) and CCMJ Systems (UK).
The TTMJ System is a method of forming panel joints in diaphragm walls. The system theoretically can be used to any depth and can be used to provide a water-stop in the joint and a tension connection between adjacent panels.
This paper follows on from the one presented at the DFI New Orleans Conference in October 2017 which outlined the principles of the TTMJ System. In this paper, further details of the system are provided and the testing carried out to date reported. The intentions and scope of the proposed full-scale field trails are then described.

Keywords: Slurry Walls, Diaphragm Wall, joints, CWS,

INTRODUCTION

The average depth of Diaphragm or Slurry Walls ('D-Walls') has increased steadily over the last 50 or so years. When the technique was first developed in the 1950s, the grabs had rounded clamshells and the joints were formed by installing steel tubes at the end of the panel and extracting them immediately after the concrete had achieved an initial set.

In the second half of 1980s the "peel off" Coffrage avec Water Stop, or Complete Water-Stop (CWS) steel joint former (Fig. 1) came into use, particularly in Europe. This became a highly successful and efficient method for forming the joint between adjacent slurry wall panels. The joint could incorporate a water bar and it was no longer necessary to extract steel joint formers in the middle of the night.

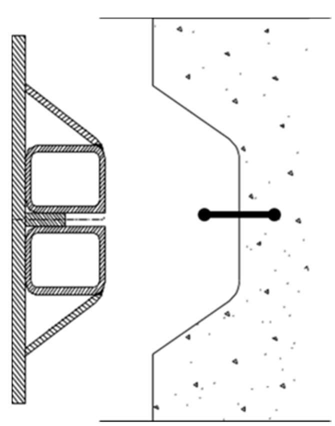

Fig. 1 – Example of a CWS

As slurry wall depths have increased, problems have arisen with the removal of the CWS joint formers. It was found that beyond 30m it was sometimes difficult, and time consuming to peel them away from the concrete of the previously constructed panel.

The TTMJ System utilises tracks cast into the ends of a diaphragm wall panel to guide a machine to trim back the concrete at the end(s) of the panel, to form a construction joint to any depth. A water-stop can be provided, and the system allows for a tension connection between adjacent panels if required.

TTMJ SYSTEM – BASIC COMPONENTS

The TTMJ Track

The TTMJ track (Fig. 2) is manufactured from pultruded GFRP and is approximately 150mm in diameter. The track has external shear strips to anchor it into the concrete and a sacrificial arc that is removed by the trimmer as it prepares the joint.

Fig. 2 - TTMJ Track

A pair of tracks, supported at the bottom of the reinforcement cage, are restrained by brackets, at 3m to 4m centres, fixed to the ends of the cage. Steel spacer straps attached to the rear of the tracks ensure that the spacing between them is constant. The restraint brackets provide some “rattle” room so that the tracks can align themselves somewhat independently from any distortion of the reinforcement cage. A typical arrangement both before and after trimming is shown below (Fig. 3).

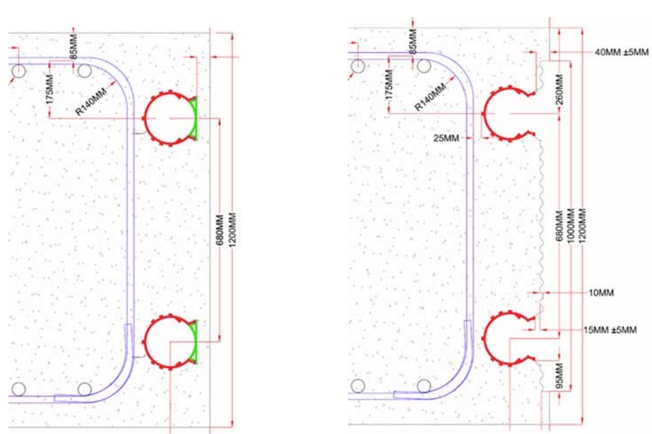

Fig. 3 - Track Cast into Panel (left) and Panel joint after trimming (right)

To maintain the reinforcement cage centrally within the excavation and ensure that there is at least 20mm concrete cover to the outside of the TTMJ track, adjustable GFRP spacers might be used. Details and a prototype of the proposed spacer are shown in Fig. 4.

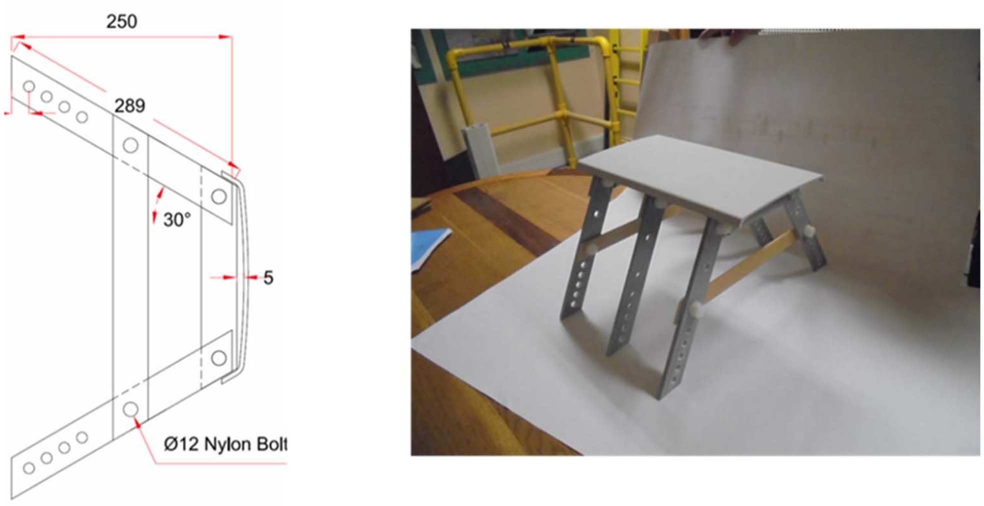

Fig. 4 - Prototype of the GFRP cage spacer

The TTMJ Trimmer

The TTMJ trimmer, currently being manufactured by TREVI, has a chain driven rotary cutting wheel. The trimmer is held in position by two pairs of guides mounted above the cutting wheel. The guides descend inside the guide tracks. The soil and concrete cuttings removed from the end of the panel drop to the base of the excavation as trimming proceeds, to be subsequently removed by grab. Air-lift or other suction systems can be used to clean the base of the panel, if preferred.

The pre-production version of the trimmer currently being manufactured has an overall height of 7.5m and a weight of 11,000kg. The cutting depth and the position of the cutting wheel relative to the guide tracks can be adjusted using the hydraulic ram located between the upper guide frame and the top of the milling machine as shown in Fig. 5.

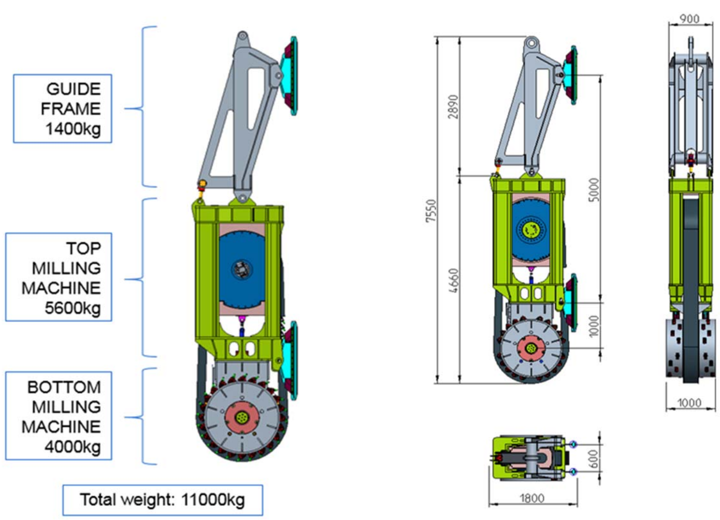

Fig. 5 - TTMJ machine dimensions and weight

For the field trials the TTMJ trimmer will be powered by and supported from a SOILMEC Hydro-Mill base machine. Later the trimmer will probably be used with either a small crane or pile rig adapted for the purpose.

The TTMJ Tension Track Arrangement

To provide a tension connection across the panel joint the standard TTMJ track described previously described is used in conjunction with friction welded headed bars. (Fig. 6).

Fig. 6 - Headed bars

Pairs of headed bars are spaced externally along the length of each track, and then a series of single headed bar fitted in the cage of secondary element is cast into the track during concreting of the adjacent panel. This arrangement forms a compression cone between the anchor heads (Fig. 7).

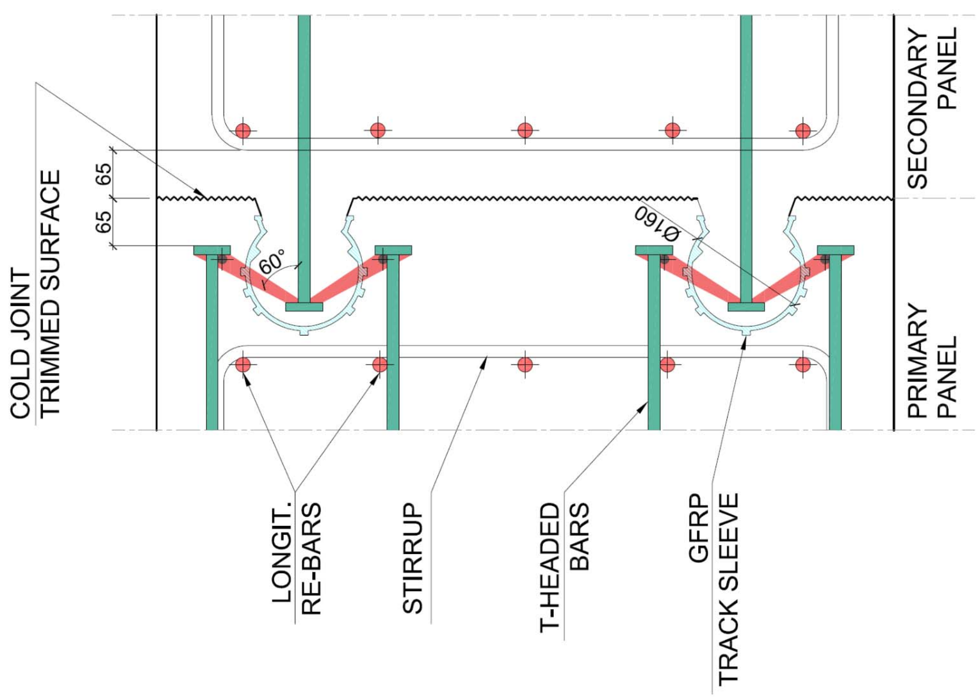

Fig. 7 - Arrangement of the headed bars for the Tension Track

The TTMJ Water Stop Arrangement

To provide an effective water stop several different arrangements were considered and evaluated. The one selected used a modified version of the TTMJ track and a PVC carrier strip to locate a hydrophilic rope in the panel joint.

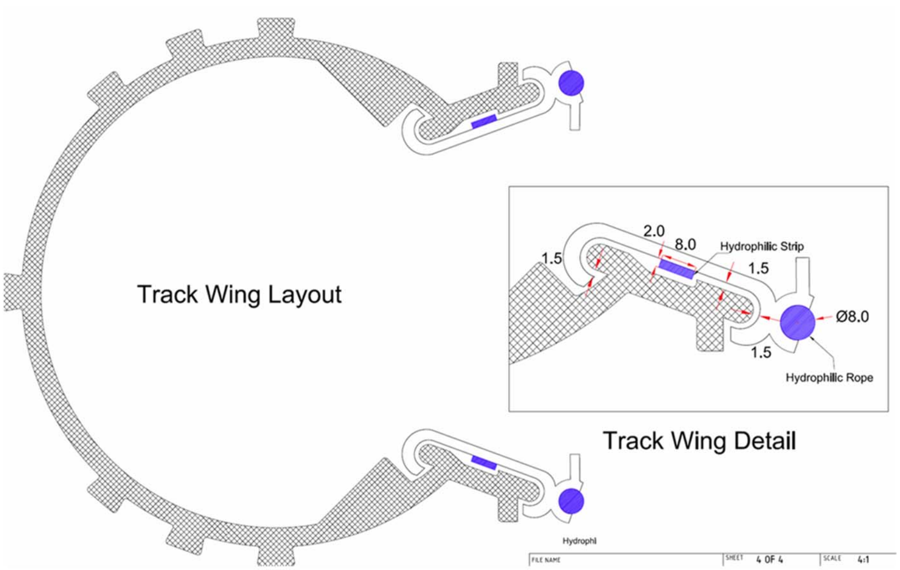

Fig. 8 - Arrangement of the water stop slipped over the track wings

Fig. 8 above shows the proposed arrangement. Sections of an extruded PVC carrier strip are slid down over the track wings. Each section will have a hydrophilic strip (shown blue in Fig. 8) glued to the rear face to prevent the possibility of water getting between the strip and the track wing. The primary component of the water stop will be a continuous hydrophilic rope (also shown blue in Fig. 8) clipped into the end of the carrier strip as it is installed into the joint. The two opposing nibs on the carrier strip are intended to act as crack inducers.

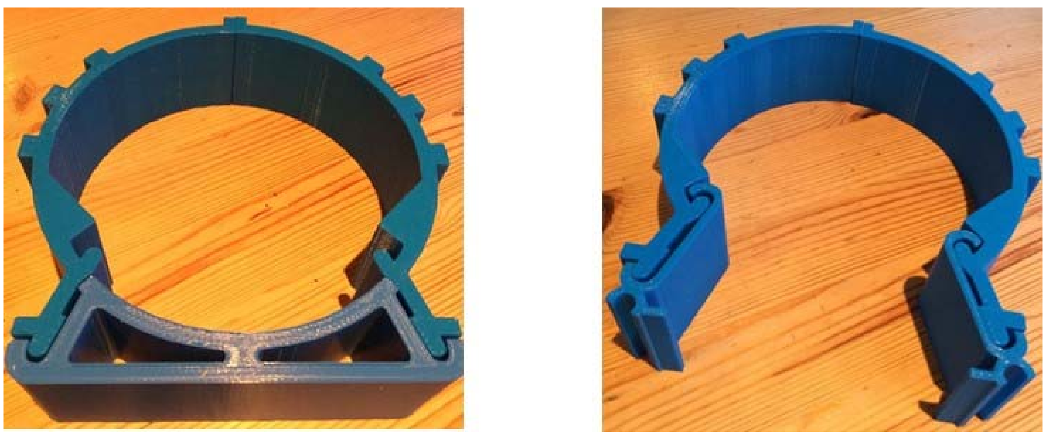

Fig. 9 - 3D print models of the proposed arrangement of water bars inserts

In Fig. 9 are 3D prints of the proposed arrangement. On the left is shown the revised TTMJ track arrangement and on the right is shown the PVC carrier strip restrained by the track wings.

TTMJ LABORATORY SCALE TRACK TESTING

The selection of the TTMJ track material and physical properties was an "educated guess". Before field trials could be contemplated it was essential that the actual restraint likely to be provided by the track was established. It was also important to determine the actual force required to remove the sacrificial arc. Additionally, the intended arrangement of the tension connection needed to be verified and the potential tension capacity evaluated. During the latter half of 2017, over 50 blocks of concrete were cast, with various track and reinforcement arrangements, and tested to destruction. The blocks ranged in size from 400mm x 500mm x 300mm deep to 800mm x 500mm x 450mm deep. For the track pull out tests the sample were tested when the concrete had a compressive strength of ±20N/mm² and for the tension tests when the concrete had a compressive strength of ±40N/mm².
Fig. 10 below shows one of the samples for the track pull out tests and Fig. 11 shows examples of the track break out testing.

Fig. 10 - Samples of track pull out tests

Fig. 11 - Samples of track break out tests

Tension testing went through several arrangements of block size and headed bar. With the optimum arrangement using 400mm long, 500mm wide and 450mm deep blocks and a single 20mm bar inside the track, failure occurred at 140KN and 150KN for the two samples. (Fig. 12)

Fig. 12 - Samples of tension track tests

TTMJ FULL SCALE FIELD TRIALS

The field trials of the TTMJ System are due to take place later this year at TREVI's sister company SOILMEC's factory in Cesena Italy. Within the facility, SOILMEC has a steel lined shaft 1.5m wide, 3.5m long and 20m deep, that will be used to carry out the field trials. There will be six cutting trials, each using two 10m long beams coupled together. Two trials will test the trimmer on samples with a flat face, two on samples with a sloping face representative of forming the joint for a circular shaft and two on samples with a bulging face (Fig. 13).

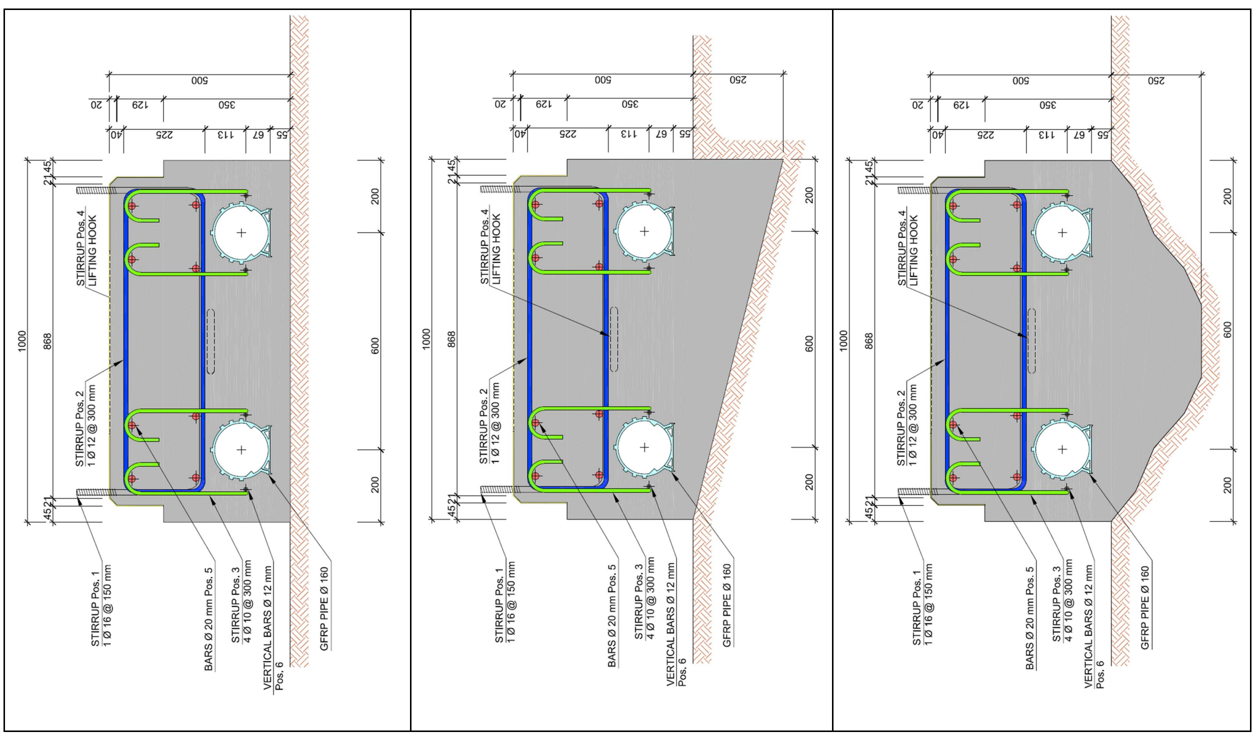

Fig. 13 - Test concrete beams - Flat face type (left), slanted face (center) and bulged (right)

The concrete beam samples are fixed to steel support beams before lifting and positioning in the test shaft, where, once the two 10m sections are jointed, a reaction frame secures them tightly within the shaft (Fig. 14).

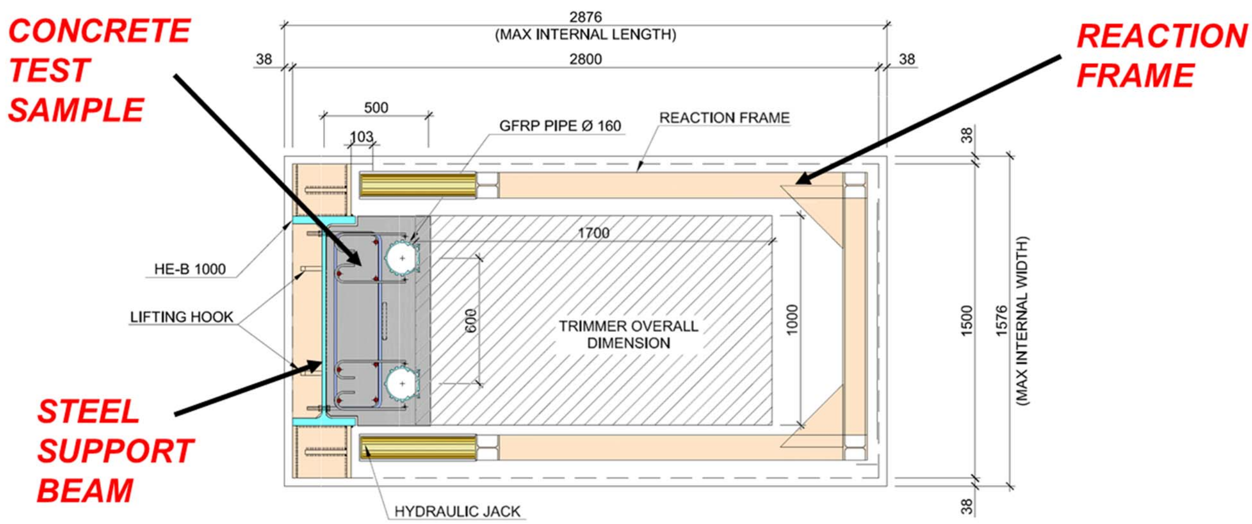

Fig. 14 - Test concrete beams – reaction frame

Once the shaft has been filled with a support fluid, to represent site conditions, the TTMJ Trimmer will be used to cut back the concrete. All control parameters will be monitored as well as rate of progress and the pull-out loads exerted on the track during the tests.

Once the sample has been trimmed, it can be removed from the shaft for inspection. At least one of the beam sections will be used to carry out a large-scale track pull out test (Fig. 15*).* A crane equipped with a dynamoter or a hydrauic jack will be used to test the restraint capacity of the TTMJ track.

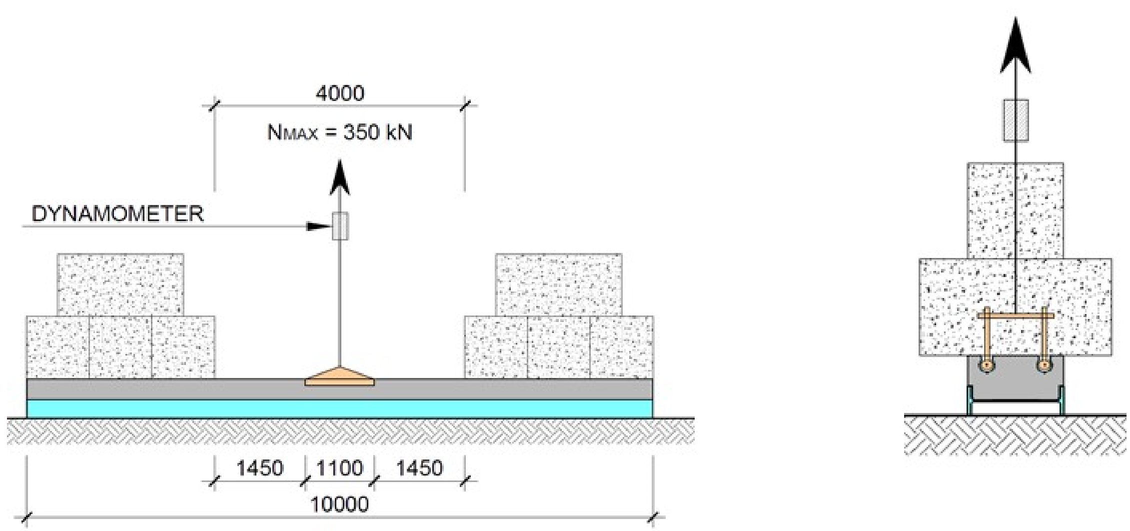

Fig. 15 - Pulling test

One more type of field trial is planned to investigate whether the tremied concrete in the adjacent panel adequately fills the TTMJ tracks cast into the first panel. A steel box will be fixed to one of the 10m long trimmed samples and then the whole assembly lowered to the base of the test shaft. Concrete will then be placed through a tremie until the steel box is filled. The position of the tremie and other arrangements will be representative of actual site conditions (Fig. 16). Optic fibre monitoring will be carried out during and after the concrete pour to assess if there are any anomalies in the concrete.

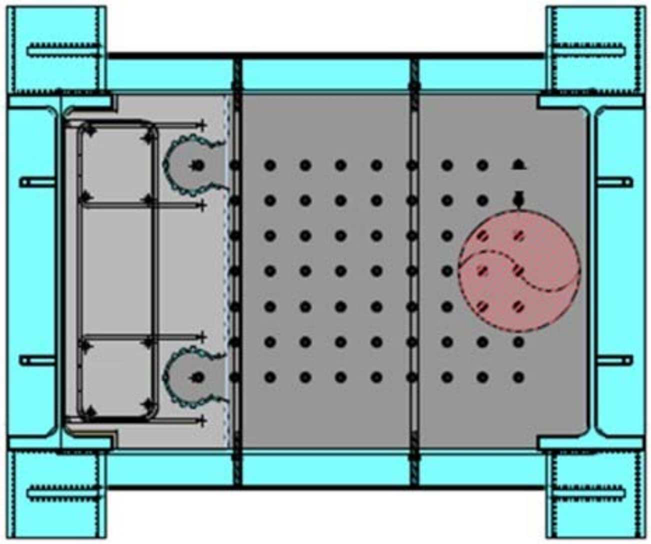

Fig. 16 - Concreting test

Once the concrete has set, the sample will be removed from the shaft and cut into sections to visually inspect the concrete and compare these observations with the data from the optic fibre monitoring.
At least one of the cut sections will be used to test the tension connection arrangement on a much larger scale than previously possible. Rock splitters will be inserted into PVC tubes cast into the concrete joint and then used to split the joint apart (Fig. 17).

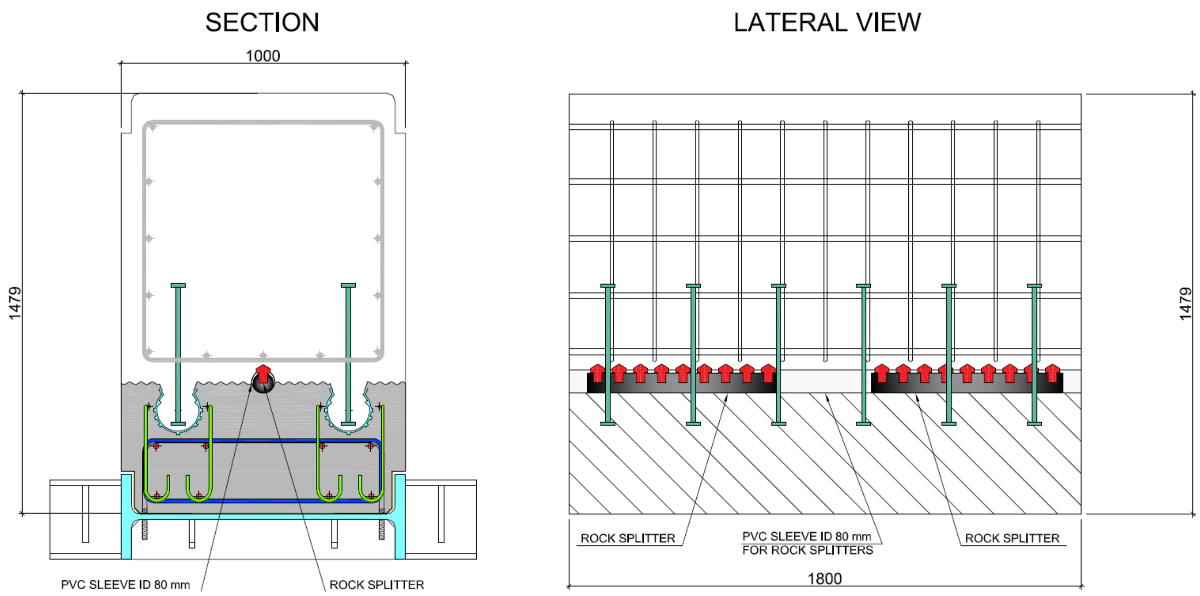

Fig. 17 - Splitting tests

CONCLUSIONS

The preliminary test conducted on the tracks demonstrated the complete suitability of the tracks to resist the anticipated traction forces exerted by the trimmer.
The design of the machine has been completed and the assembly of the components is currently ongoing.
A complete suite of several tests has been envisaged to provide a full picture of the potential of the method and to satisfy the designers.
The TTMJ System is a step change for diaphragm walling, because the system will offer:

- Technically superior panel joints to greater depths than currently achievable.
- A tension connection between adjacent diaphragm wall panels.
- An effective water-stop in the joint.
- Potential cost savings of up to 20% on diaphragm wall projects.
- Programme benefits on diaphragm wall projects.
- Improved Health & Safety control of site operations
- Improved Risk Management

ACKNOWLEDGEMENTS

Unfortunately during the period of preparation of this paper, Julian Crawley, after a long and brave battle with cancer, passed away. His love of life, enthusiasm for the TTMJ system, and dedication to its development set an example for the other members of the consortium team and provided the encouragement to solve the problems encountered along the way.

Reference List

Crawley, J., Siepi, M., van Horn, P., Coupland, J.: TTMJ – The New System For Slurry (Diaphragm) Wall Joints. Proceedings of the 42nd Annual Conference on Deep Foundations, 2017, New Orleans, LA, USA, 379 p.