Lined formwork for the casting of curved and inverted concrete surfaces for a major siphon weir

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ABSTRACT: The casting of concrete in conventional wooden formwork is a well-known procedure, but the resultant surface finish is often poor. The use of a geosynthetic liner on the inside of the formwork, together with appropriate perforation of the formwork, permits a marked improvement in both the quality of the concrete itself and its surface finish. Where inverted surfaces are present in moulds and where the concrete end use is particularly demanding, the use of a geosynthetic lining is particularly beneficial. It has been found that the elimination of the need for hand finishing makes it a cheaper process than the use of high quality wooden formwork alone.

1 INTRODUCTION

The River Mersey is one of the U.K.'s larger rivers, reaching the sea near Liverpool and draining the Lancashire and Cheshire plains. Before the construction of the Manchester Ship Canal, there was little if any level control of the Mersey and the plains suffered from frequent flooding. The Construction of the Canal made a great difference to this situation, creating a straight, well dredged channel from Manchester to the sea at Liverpool. The Canal essentially runs along the course of the Mersey and the hydraulic regimes of the two are intertwined.

As a part of its responsibility to maintain drainage, the Manchester Ship Canal Company decided to bypass one of the Mersey's large looping meanders by cutting across the neck of the meander. See Figure 1.

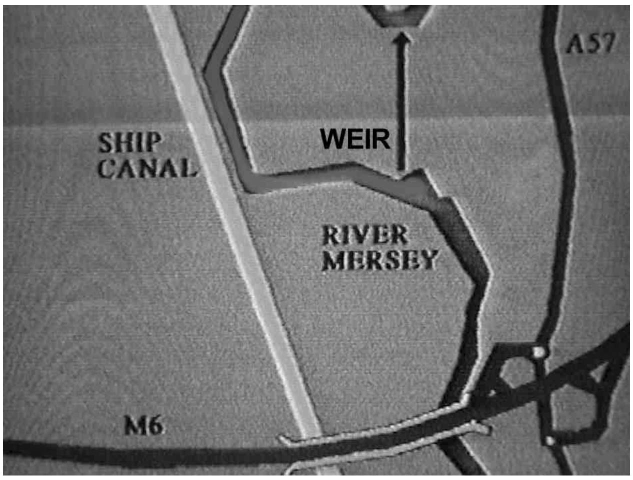

Figure 1. Schematic plan showing the weir cutting across a meander close to the M6 motorway in Lancashire, U.K.

At this location there had been two older manual weirs which required constant control to regulate the floodwaters upstream and which moved physically, requiring maintenance and electrical power.

The Ship Canal Company decided to construct a modern siphon weir instead of a mechanical one. It would be, to the Author's knowledge, the largest siphon weir in Europe. The Author's company was commissioned to design and supervise the construction of this weir in conjunction with Hydraulic Engineering Ltd. of Wallingford - the U.K.'s premier hydraulics research institute.

During operation, normal river flows pass on either side of a centrally positioned siphon structure as shown in Figure 2.

Figure 2. Photograph of weir with central siphon section at normal flow level.

The working concept of the siphon is that, when the river water starts to rise during periods of heavy rain, eventually the water level reaches the siphon lip, creating a vacuum, which sucks the water through the siphon at great speed. This discharges the river at a much greater rate than gravity could achieve. The discharge rate is so great that the floodwater is rapidly moved downstream and the floodwater subsides. As the upstream level falls, the siphon is automatically disengaged and ceases to function.

The whole procedure is automatic, needs no supervision, needs no maintenance and uses up no external energy. It is the ultimate in environmental friendliness.

2 CONSTRUCTION OF THE SIPHON

In order to work at peak efficiency, the siphon has to be constructed with the following features:
a) It has to be made of concrete to absorb high levels of vibration from the high velocity water passing through the siphon.
b) It has to be constructed with very smooth internal surfaces to resist the creation of pitting and damage to the concrete caused by cavitation in the high velocity stream. Cavitation is the formation of exploding vapour bubbles caused by high vacuum conditions in the siphon. These bubbles are known to form on ships' propellers causing severe erosion of the metal, and in the discharge races (tunnels) from large dams down to hydroelectric generators.
c) It has to be constructed with curved inverted surfaces which are notoriously difficult to form and fill with reinforcement and concrete.

The author had been involved with Japanese engineers of Kumagai Gumi some fifteen years ago, who had developed the use of geotextiles for concrete formwork and he decided to use geotextile liners on the wooden formwork to produce the high quality of concrete needed for this arduous purpose. Originally, the Japanese had worked solely with woven textiles, but over the last ten years, U.K. manufacturers have produced nonwoven spunbonded textiles for the purpose.

The use of the textile has remarkable benefits on the concrete as listed below:
a) The surface is formed very smoothly without bubble marks or chemical deposits. This smooth surface eliminates the need for extensive reworking by hand with cement to make the surface smooth after casting. Most remarkably, this can be achieved on inverted surfaces of the mould, where bubbles and chemicals usually collect.

The use of a geotextile liner on a perforated wooden formwork results not only in a virtually perfect surface finish to the concrete, but also improves its mechanical and chemical resistance properties considerably. Figure 3 shows the basic principles of how the textile is deployed in relation to the formwork.

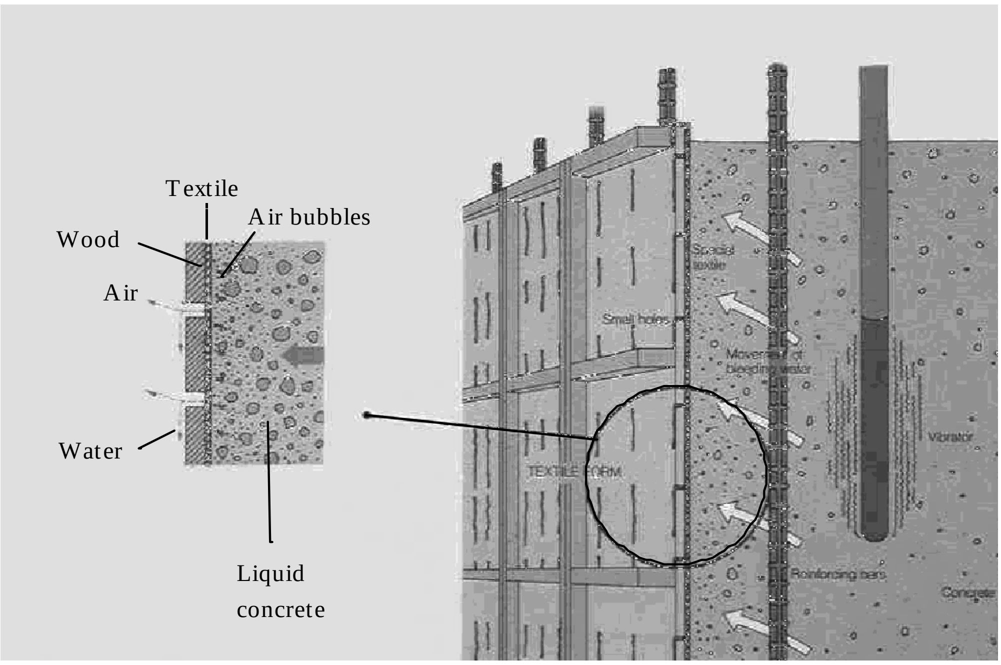

Figure 3. Sketch showing how water is released from setting concrete through a textile liner.

b) The hardness of the concrete is increased, particularly near the surface between the steel reinforcing bars and the surface. This is the most important part of the concrete and the improvement leads to a substantially increased life expectancy. The increased hardness is obtained by virtue of water passing out (with air bubbles and chemicals) through the formwork, thus changing the water/cement ratio near the surface. A lower percentage of water leads to a harder concrete.
c) The concrete between the surface and the reinforcement is considerably increased in resistance to freeze-thaw cycling.
d) The concrete is considerably improved in relation to carbonation degradation.
e) The concrete is considerably improved in relation to salt penetration, which attacks the steel.

The Author was particularly aware that the casting of concrete within curved moulds would be problematic, and assessed that geotextiles would be the solution to the problem.

Tender documents were prepared allowing the contractor several weeks of pre-construction trials in which to make large scale test batches of concrete using inverted surfaces. This was undertaken whilst early earthworks were being constructed. In fact, this was a very useful exercise to be highly recommended to others. At first the contractor had difficulty in forming the concrete well. However, it was found that trial and error improved his handling and his capability such that within the period he was ready to construct the main structure.

The relevant matters that needed addressing on this difficult project were:
a) The choice of textile.
b) The method of fixing the textile to the formwork.
c) The size and spacing of holes in the formwork.
d) The type of wood needed to make the formwork.
e) Placement and vibration of the concrete within the mould.

When the Japanese first developed this technique, they worked with woven fabrics in the belief that they would be better than nonwovens by experiencing less degradation when reused. It was found that for large, repetitive shapes, lined formwork could be used several times before having to have the lining replaced. Polyester woven textiles were smooth and they were improved by using spray release agent on the textile to assist the formwork to shed from the mould after casting. In this way, ten or more reuses could be made. However, during recent years nonwoven geotextiles have been used which are less expensive and can be used for several repetitions of casting. The author decided to try these because the surface finish to be expected was even smoother than wovens, not exhibiting the cast of the woven structure. Smoothness was of paramount importance to this project. In some engineering applications, wovens impart an attractive surface texture, which allows an applied finish to grip well. However, in this case there was to be no surface painting or other finishing, so smoothness and hardness were the two critical criteria.

One of the more interesting aspects of the testing program, which emphasises the need for individual testing in all cases, was the development of a successful hole size and spacing in the wooden formwork. Initially, holes of about 8 mm diameter were drilled at 150 mm spacing in a grid through the formwork. At first sight this appeared to be successful, but when the hand was stroked over the concrete, a regular very gentle undulation could be felt - a gentle formation of dimples where the holes had been. Too gentle to see, but not suitable for the demanding hydraulic environment. By experiment, the resident engineer adjusted the hole sizes and spacing so that the holes were smaller and more frequent, until the dimpling did not occur. Around 5 mm diameter at 100 mm spacing seemed to be ideal. It seems that these dimensions must be judged by trial on site, since they will depend upon the concrete mix adopted and the type of textile chosen. The dimpling was being caused by a localised loss of fines through the textile and this will vary with the concrete mix and the textile's properties.

For the straight-sided forms, the textile was spread out and hand tensioned before being stapled to the sides of the formwork. This method worked well. However, where inverted surfaces had to be formed, to prevent the textile from falling away, an adhesive spray was used. This was applied to both inverted and concave mould surfaces.

The fact that a textile was used for the inner facing of the formwork meant that an inexpensive rough timber could be used for the formwork. This saved money. Figure 4 shows the 200 g.s.m. spun bonded textile being attached to rectangular formwork.

Placement of the concrete into the complicated mould shapes was enhanced, because a slightly wetter mix could be used than would be considered otherwise. The wetter mix had a better flow capability and thus penetrated the mould and the reinforcement well. Vibration of the wet concrete now not only settled the concrete into the shape, but also expelled the water and expelled the trapped air vigorously through the holes in the formwork.

Figure 4. Fixing the textile to the wooden formwork. Stapling edges.

Once the textile is fixed to the formwork, it can be assembled in the normal way, but more complex forms can be considered than previously, since air bubbles can now be dealt with. Figure 5 shows an inverted form being removed.

Figure 5. Sloping formwork being removed from a moulding.

The beneficial effect of casting concrete with a textile liner can be seen in Figure 6. The excellent results are apparent. The left hand side of the photograph shows the smooth finish obtainable with a textile liner, whilst the right hand side shows the bubble formation typically associated with concrete pouring in wooden formwork.

3 SUMMARY

A nonwoven textile was used to line timber formwork for the casting of complex curved concrete shapes and surfaces for what is possibly Europe's largest siphon weir. Textiles were used because they imparted very smooth surfaces of increased hardness and corrosion resistance. The project was successfully completed by a contractor with no previous experience of geotextile lining work, by virtue of allowing an early stage-testing period in the contract.

This siphon weir has been in successful use for over five years and has helped to automatically control river levels, reducing flooding and helping the environment in the north west of England.

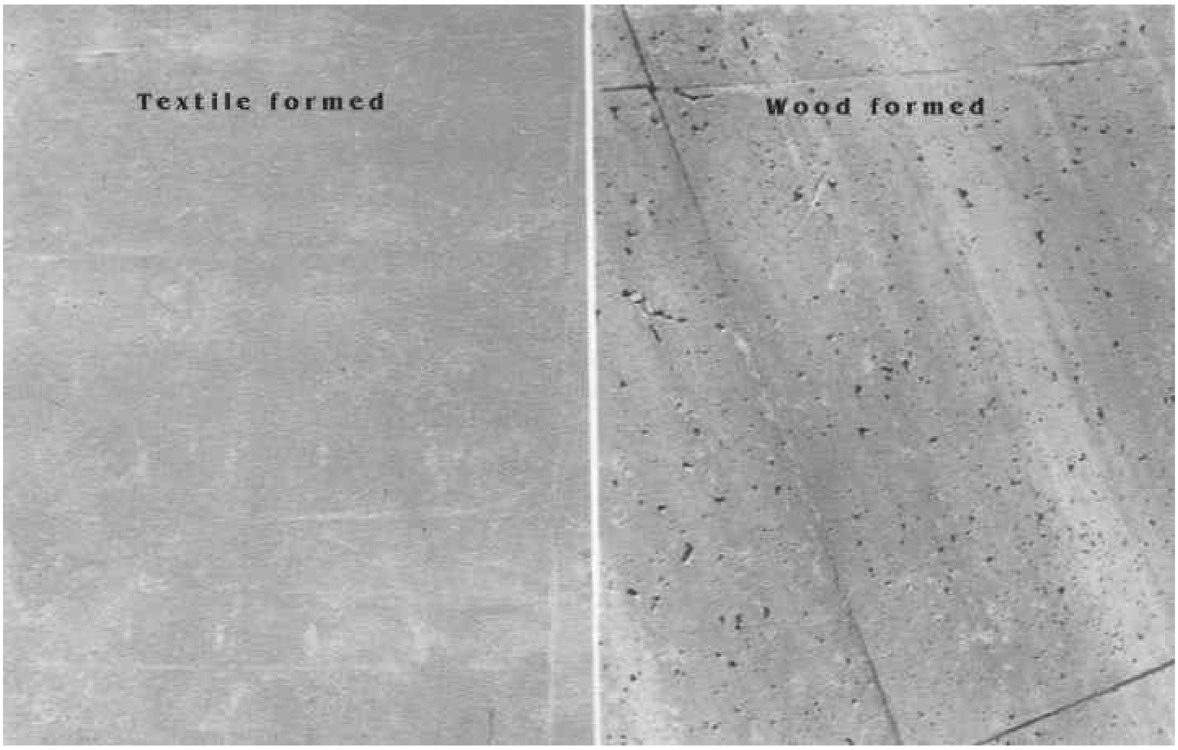

Figure 6. Comparison of smooth textile-formed concrete and normal formed concrete.

4 CONCLUSIONS

Nonwoven geotextiles can be successfully used to line concrete formwork for the high specification finish of concrete in major civil engineering applications. Inverted and curved surfaces can be formed free of air bubble pockets and chemical deposits.

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