A Fast And Flexible Technique For Watertight Construction

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Summary

This paper presents a technique that enables important savings to be made in the construction programme, while at the same time allowing the realisation of watertight structures. The approach is based upon an analysis of the structural system, the life cycle load patterns, the water table variations and the construction sequencing. The joint layout and detailing are then designed to accommodate the anticipated movements using a combination of patented re-injectable channels, crack inducers, movement joints and waterstops. These elements are installed before concreting and subsequently injected with a two component hydrophilic resin, mixed and injected using a purpose built pump. The pressurised resin penetrates all potential water paths, where it polymerises and subsequently swells in humid environments to provide a waterproof seal. The system has demonstrated successful performance since its development and commercialisation in 1965.

Keywords: flexibility, fast-track construction, durability, economy, crack-management, waterproofing

1. Introduction

Waterproofing a reinforced concrete structure, and particularly one whose lower levels are in contact with groundwater can be a difficult exercise, which in the event of failure can have disastrous results. In the case of a new structure and after assessment of the risks, waterproofing solutions are selected and incorporated during construction. Problems arise when the risk of water ingress changes, due to changing environmental conditions, movement of the structure or failure of the chosen waterproofing system.

Ground water levels may change due to changes in patterns of water runoff or due to flooding and consequential differential settlement. Waterproof membranes may be punctured during backfilling; waterstops may be poorly installed prior to, or displaced during concreting. Alternatively, in the case of a diaphragm wall, leakage may result from construction faults or difficult ground conditions. Whatever the reason, the consequences can be expensive and sometimes dangerous; consider the case of an underground transport system where the traction current flows through rails. To a lesser extent the ingress of moisture can create unhealthy conditions for the users. A great deal of additional expense may be incurred rectifying faults, both immediately before and after commissioning, when access for maintenance is limited by operational demands.

This paper discusses an alternative approach to waterproofing, developed and patented by the Swiss company, RASCOR International Ltd. Their waterproofing systems include a specially formulated environmentally friendly resin that has been developed and in use since 1965 and several different HDPE elements, which may be injected and even re-injected to maintain a watertight environment. For the construction professional, this approach offers advantages in terms of increased flexibility of construction as well as frequent savings in material and construction time.

The paper will focus on three different case studies illustrating the advantages of this approach.

2. Thames Tunnel, Channel Tunnel Rail Link, UK

Fig 1: West Portal

Contract 320 on the new TGV Channel Tunnel Rail Link provides the Thames Tunnel carrying the line beneath the river, east of London on its route into the City. In the initial design phase various options were investigated, including A and B (shown in Figure 2) as part of the design optimisation process. The conventional cut & cover option A with external membrane, is shown adjacent to a more economic solution, option B, based on the use of watertight diaphragm walls and inter-spanning horizontal slabs. Due to the improved quality of diaphragm walls over the last decade, the designers chose option B, considerably reducing the construction time. A risk analysis determined that one of the key issues was the water tightness of the final structure.

Following early consultation with all parties concerned, including Rascor Engineering Ltd., it was agreed that effective sealing could be achieved if certain design parameters were met. Detail calculations were made of anticipated shrinkage, settlement and joint rotations for each load case and structural element, including variations in temporary works loading and water levels.

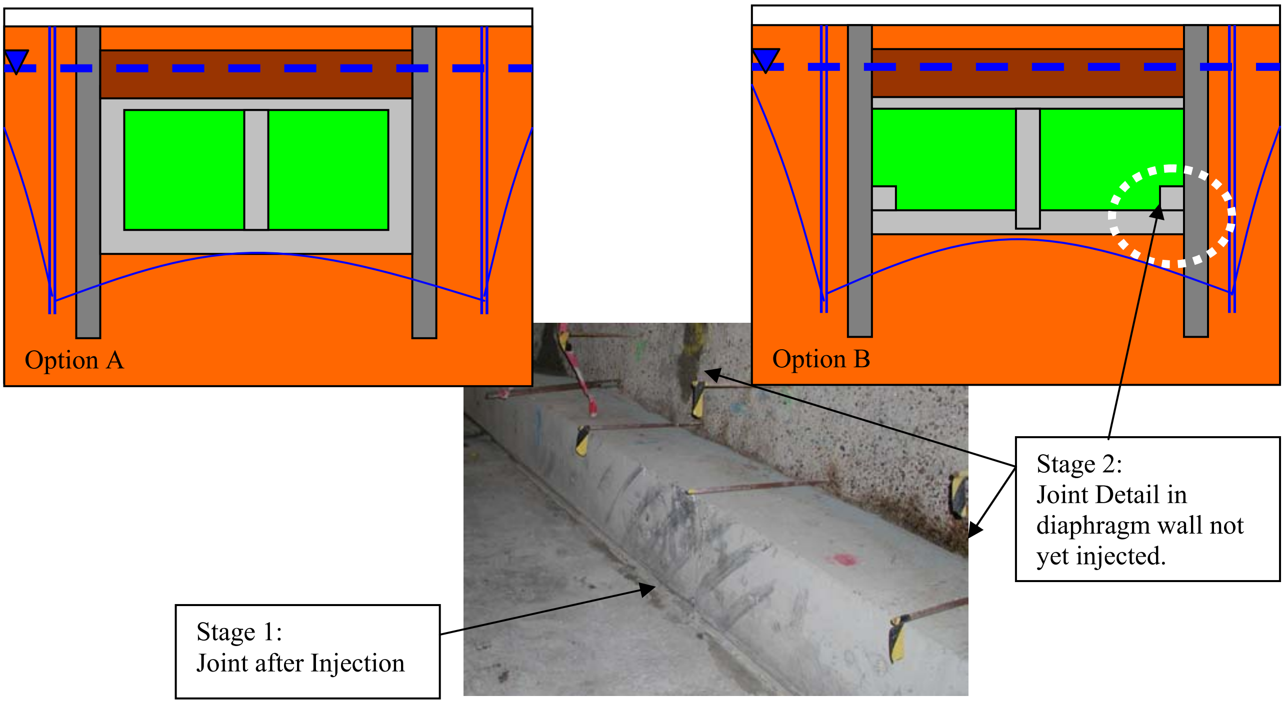


Fig 2: Comparison of Construction Options

Waterproof joints between diaphragm wall panels, as well as horizontal joints with the interspanning slab were achieved using re-injectable channels and the two component hydrophilic resin.

The Contractor had based his offer on a combination of construction methods working in parallel; a fast track cut and cover solution for the main ramps and a TBM solution for the section under the river. This posed an additional waterproofing problem at the joint between the two different types of tunnel i.e., between an open cut box section and a circular segmentally lined driven tunnel. This was overcome by a proposal already proven by Rascor for a similar situation on the West Rail Project in

Hong Kong. The adopted solution was again the use of re-injectable channels and the two component hydrophilic resin.

Fig. 3 Joint between TBM and Cut & Cover sections

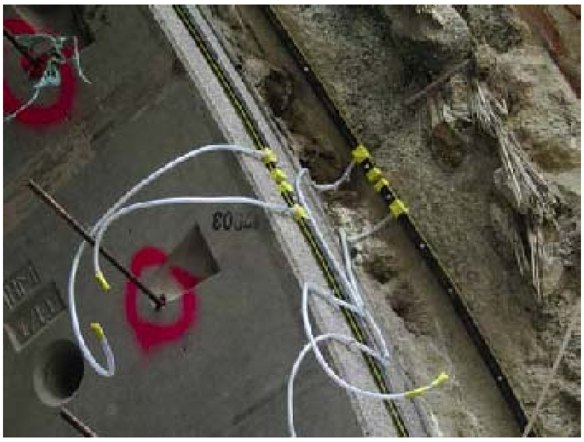


Fig. 4 Joint detail showing injection channels

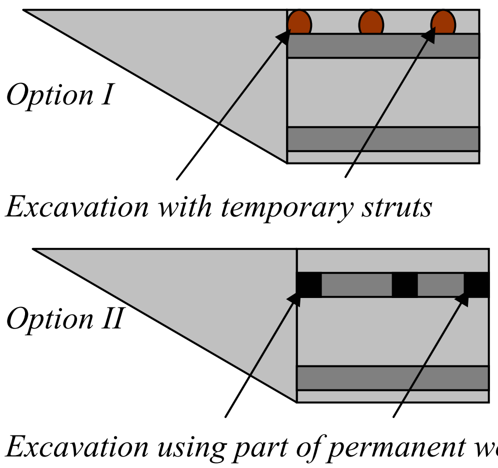


Fig. 5 Alternative methods of strutting the excavation

Had the contract structure allowed it, the chosen temporary works solution could have been further optimised in light of the adopted waterproofing system. This alternative, shown here in Figure 5, would have allowed the temporary steel props (Option I) to be avoided in favour of casting sections of the deck slab on the ground (Option II) and excavating between them. The joints between the diaphragm wall and the slab sections, together with those between the sections, would have been sealed using pre-installed channels and resin injection.

3. Rail 2000 cut and cover tunnel, Thunstetten, Switzerland

Fig. 6 Overview of Tunnel Thunstetten

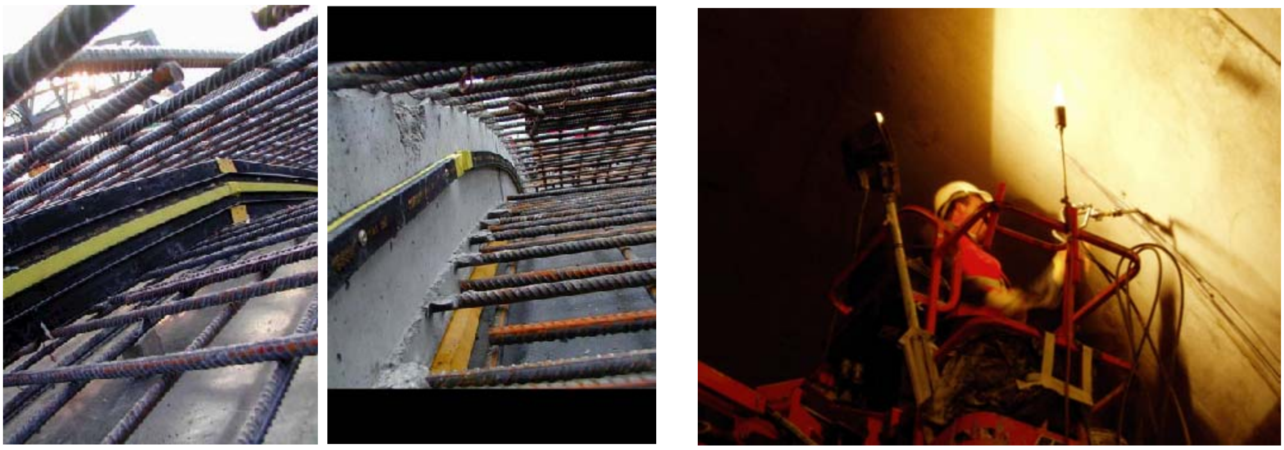
After unforeseen delays in the planning of the Rail 2000 project together with delays in approval of the final alignment, the Swiss Railways were under pressure to recover lost construction time and to provide tunnels for what originally was to be an open-cut track. This situation obliged the Contractor to seek alternative solutions that could offer considerable savings in time and money to offset the required design changes. Rascor were approached to investigate potential options.

The project was initially designed to incorporate a traditional approach to waterproofing using expansion joints, membrane system etc. An alternative proposal was made which called for the use of a radically different method of tunnel construction and waterproofing, based on the "White Tank" System Rascor, which allows the use of single pass tunnel linings without membranes, and comprises the reinforced concrete mix design, crack management and waterproofing work as a complete package, with a single point of responsibility, including a 10 year insurance backed guarantee against water ingress.

Fig. 7 Fixing steel and crack-inducer elements prior to concreting

The philosophy behind the realisation of the single pass waterproof structure is to allow the tunnel to develop radial cracks at predetermined intervals along its length. Expansion joints are replaced by special elements placed within the reinforcing steelwork to induce cracks. These are subsequently injected with a high performance resin. Waterproof concrete was used to a maximum. Figure 7 shows an 18 metre length of tunnel being prepared for concreting. The cracks were injected from the inside and consequently backfilling could begin as soon as the concrete reached its 28 day strength. Three techniques were used to seal the structure. This combination gave great flexibility in construction and removed waterproofing activities from the critical path.

Figure 8 shows two of the techniques employed. The left hand photograph shows the re-injectable crack-inducer elements fixed within the steelwork cage. The middle photograph shows the channel elements in use for construction joint sealing. After concreting, both systems are sealed by drilling through concrete into the elements and pumping the two component hydrophilic resin under pressure. The third technique involves drilling across crack planes and injecting the hydrophilic resin, allowing any random cracks to be sealed. Note that the latter method is also ideal for crack repair in existing structures.



Joints formed by crack-inducer and sealed by resin injection

Cold joint sealed with channel and resin injection

All resin injection carried out from within the tunnel

Fig. 8 Joint / crack management

The absence of external membranes allowed the contractor to save time when excavating and backfilling. The net effect was to reduce double handling of the excavated material and reduce the effects of inclement weather conditions, which can delay earthmoving activities during up to 40% of the year. The schematic in Figure 9 shows the sequencing of joint/crack formation and injection.

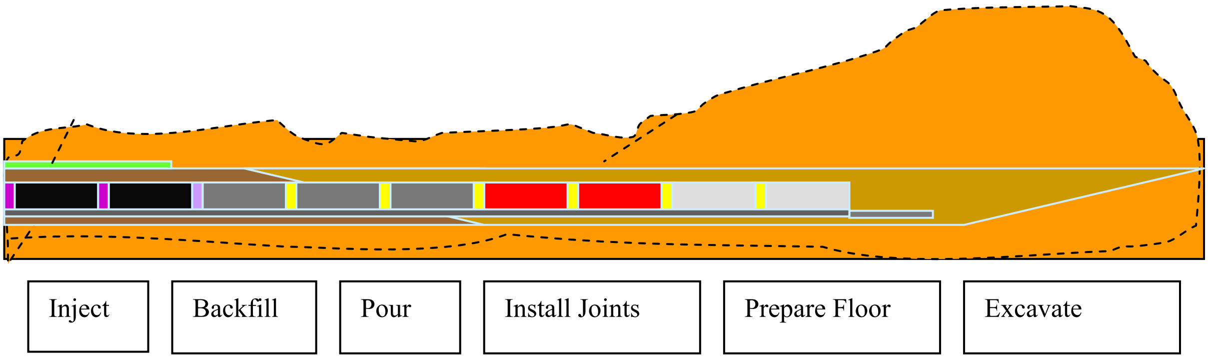
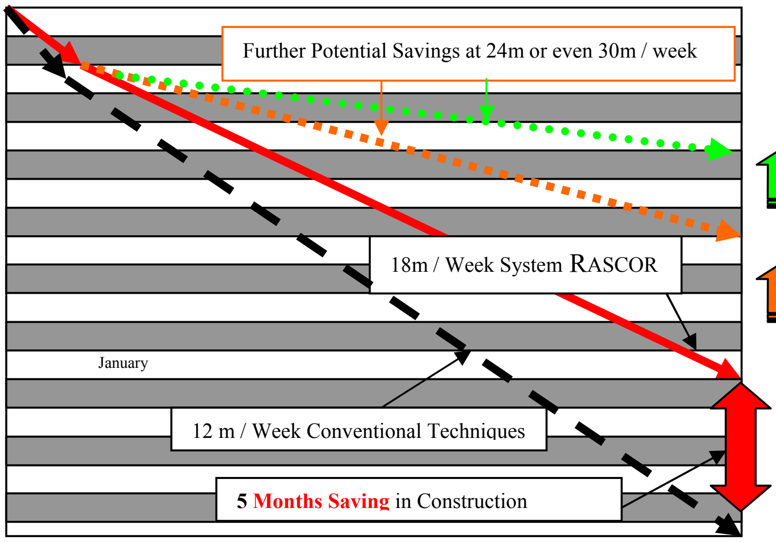


Fig. 9 Schematic showing the joint installation sequence (running from right to left)



Moreover, soon after the start of the contract and during the site preparation activities, the shuttering supply subcontractor was facing internal supply problems and eventually was declared bankrupt, resulting in a further 5 month programme delay. This additional time constraint was easily absorbed within the overall savings offered by the chosen solution. Further potential savings could have been met had longer lengths of shuttering been available. The impact of the adopted solution on construction times is shown in Figure 10.

Fig. 10 Actual and potential shortening of program

4. The new Hyatt hotel, Zurich, Switzerland

The congested nature of this inner city site made the construction flexibility introduced by the choice of crack management and waterproofing system very attractive.

The new Hyatt hotel is a 6 storey structure comprising a 3 level basement car park extending below the ground water table, in the busy central financial district of Zurich. The lack of space, as seen in the diagram below, demanded careful construction programming and resulted in a top down and parallel bottom up approach. This was largely facilitated by the inherent construction flexibility resulting from the use of re-injectable resin based waterproofing systems. These were integrated into the design philosophy before and during construction.

Furthermore, the decision was taken out the outset to adopt a “White tank” solution for this structure. The concrete mix was optimised to provide the minimum cement content of 280 kg/m3, which in turn reduced the amount of heat of hydration. The design philosophy also allowed a significant reduction in the quantity of anti-crack reinforcement in places with up to 20 % reduction in the amount of distribution steel.

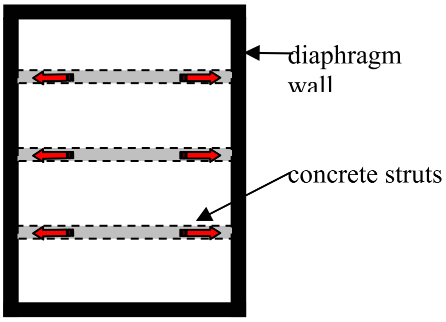
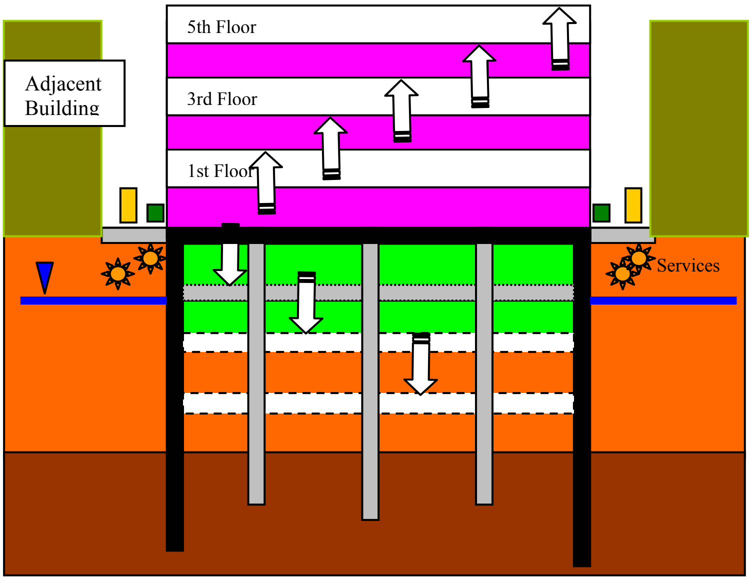


Fig. 11 Plan view of concrete struts incorporated into permanent works

Temporary steel struts and concrete beams (stage 1 of basement floor slabs) were poured on the ground as excavation of the basement levels proceeded. Figure 11 shows a schematic plan view of the hotel diaphragm walls, indicating how parts of the permanent floor slab were used to provide temporary strutting.

A range of injection elements was installed prior to concreting. The injection operation is shown by the photographs below in Figure 13.



The structure was built up and down from the ground floor in a parallel operation as shown below by the schematic Figure 12. This method of construction allowed the reinforced concrete structure to be completed in 13 months. The works, which started in January 2003, are scheduled for completion in 2004.

Fig. 12 Schematic showing the parallel construction up and down from the ground floor

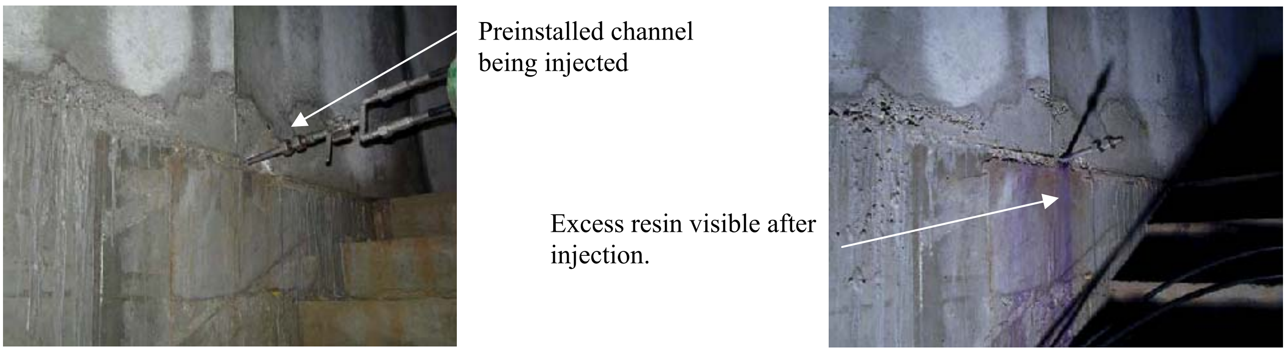


Fig. 13 Resin injection underway

5. Conclusions

The subject waterproofing system adds flexibility to the construction sequence allowing a holistic approach to design and construction providing:

- the designer with freedom of choice regarding structural forms and,
- the constructor with the means to optimise his overall programme with associated cost savings, and additionally, to realise savings in resources (crack reduction steelwork, backfilling).

The system also provides a flexible solution for the engineer faced with the increasing need for a soft systems approach to project management due to the complexity and unpredictable nature of many building programmes.