Use of Fibre Reinforced Polymer (FRP) Reinforcement Constructing Diaphragm Pit Walls

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Summary

FRP is an anisotropic composite material with a high tensile strength in axial direction and a high resistance against corrosion. The anisotropy of the material is quite advantageous at excavation pits for the starting and finishing processes at automated excavation like tunnel boring machine (TBM) and pipe jacking. Concepts of design and their economical advantages are demonstrated by means of projects. For the first time in Germany the FRP reinforcement has been used at diaphragm pit walls at the construction of the metro line stations "Brandenburger Tor" and the North-South-Line in Cologne. Based on the derived design method the final design of the diaphragm pit walls was carried out and the successful functionality was checked during construction phase.

Keywords: design model, temporary constructions, mechanized tunnelling, pipe jacking, break through of pit walls, new materials.

1. Introduction and Fields of Application of the FRP

In order to apply mechanized tunnelling methods, tunnel boring machines (TBM) are installed into existing deep excavation pits with highly reinforced pit walls. TBM’s of today are not capable of passing through steel reinforced pit walls. Appropriate additional methods are necessary to manually recover the reinforcement in the pit walls before the machines can pass through.

The second and economic option is to replace the steel inside the pit walls with a material that takes over the static and constructive functions of the reinforcement and can be chipped by the TBM. An optional material is an reinforcement made of glass fibre reinforced polymer (FRP).

Furthermore, the unidirectional fibre alignment leads to a linear-elastic stress-expansion relationship. When the maximum stress value of more than 1.000 N/mm² is reached, expansions of almost 25 % are obtained and therefore a FRP reinforced concrete component shows a ductile behaviour, because deformations and crack initiation can lead to failures.

Various tunnelling projects offer different possibilities of applying FRP reinforcement. The FRP reinforcement has both constructive and static functions. The areas of application of the reinforcement are explained by two current inner-city infrastructure projects:

1.1 North-South Line Cologne

The track areas of North-South line are excavated by hydro shield TBM. In order to optimise construction time and costs, the existing diaphragm pit walls and the not excavated pit areas are passed through. To facilitate the passing of the shield machine through the diaphragm pit walls, the diaphragm pit walls are reinforced with a FRP reinforcement. This reinforcement only has constructive functions to connect the lower and upper part of the reinforcement-basket.
1.2 Meto Line Station “Brandenburger Tor” Berlin

When constructing the metro line station “Brandenburger Tor”, Berlin, the platform was designed by means of mining construction methods backed by icing. To achieve this, 30 micro tunnels with a diameter of 1,50 m had to be excavated out of the 22 m deep excavation pits for the ascent building. The total length of the tunnelling is 2,7 km. The approaching walls in figure 1 show that the pit wall is extensively traversed by the 15 micro tunnels. This pit wall has static functions in the different excavation phases and has to include the earth and water pressure (approx. 200 kN/m²). This leads to a high percentage of reinforcement - 180 to 200 kg/m³. Keeping the approaching areas of the pipe jackings clear of reinforcement is not possible in this case.

2. Design Methods

The need for development of a concept for verifying the statically-required reinforcement is highlighted in the absence of standard provisions or an absence of general technical approvals. The following points in particular were taken into account compared with the dimensioning with SRC reinforcement:

- the effects of time- and temperature-dependent behaviour on the definition of the permitted dimensioning stress or the material’s characteristic curve.
- influence of the linear-elastic material behaviour on the specification of the coefficient of safety
- distribution of the internal forces on the concrete steel- and FRP-reinforcement taking into account the differing material characteristic curves
- reduction of the transverse load-carrying capacity because of large thrust cracking widths resulting from the limited E modules
- effects of the altered shape on the compound properties.

3. Conclusions and Outlook

Experiences in Berlin and Cologne have shown that FRP reinforced pit walls represent real economical and technical alternatives to conventional solutions. In particular, the ability to dispense with additional measures to secure the approach and entry procedures for the TBM is of benefit here.

Up to the start of 2007, neither general building supervisory approval nor binding standards regulation is in place in Germany for the dimensioning, design and construction of FRP-reinforcements. It is nevertheless to be assumed, in view of the positive experience with the projects now completed, that future procedures for granting approval for specific projects in individual cases can now be carried out more quickly, thus reducing the planning uncertainty as to how long the procedure will last.

Through the experience already gained, incorporated into the dimensioning concepts are new insights which make economical and practical application a real possibility, but without disregarding the testing phase, which has so far been limited. Especially with respect to the thrust dimensioning, it appears that even more economical dimensioning concepts could be realised, given additional research activities.