

Corrosion and bond behaviour of galvanized steel in concrete with chromate reduced cements

Due to the EU guideline 53/2003/EG which is valid since 2005 the content of soluble chromate in cements is limited to maximal 2 ppm. Hereby an increased initial corrosion of the zinc layers at galvanized structural elements or galvanized reinforcing steels is expected. Beside the chromate content also the alkalinity of the used cements could have a significant influence. It is suspected that the generation of hydrogen at the bond zone galvanized steel/concrete adversely affect the bond behaviour between galvanized steel and concrete matrix.

The objective of the research project was to investigate the effects of the chromate reduction on the corrosion behaviour of zinc layers in fresh concrete. Furthermore, the effects on the bond behaviour should be described und assessed with respect to changes relevant for practical applications. To answer these questions electrochemical measurements as well as pull-out tests were carried out using an extensive test matrix. Cements of the types CEM I, CEM II and CEM III with and without chromate reduction were taken prior to and after the addition of the chromate reducing substance. Hence, they each belong to one charge. This ensures that differences in the corrosion and bond behaviour can be definitely traced back to the influence of chromate. The effect of the alkalinity was investigated with CEM I by specific modification of the initial charge.

The electrochemical measurements have shown effects on the corrosion behaviour and the formation of the surface layer for all series tested. Pronounced differences were found for CEM I and CEM II while they were considerably lower for CEM III. The test series containing chromate for cements CEM I and CEM II have shown significant inhibition of the zinc corrosion in the early stages. Thereby the amount of corrosion hydrogen generated prior to solidification of the concrete is reduced. At test specimens with chromate reduced cements this inhibition was not observed. Investigations of the bond zone clearly show a pronounced pore formation in the area of the interface galvanized steel/concrete matrix which can be ascribed to the strong hydrogen evolution at the galvanized steel in the fresh concrete. For CEM III such difference was not determined. As the chromate content is already lower in the initial state due to the smaller fraction of Portland cement clinker a significant effect on the pore structure of the bond zone was not observed.

The electrochemical investigations as well as the formation of the bond zone revealed no noticeable differences for the specimens with increased Na_2O -equivalent. In the pull-out tests slightly reduced bond stresses were observed for the modified specimens.

When a contact element between steel and galvanized steel is formed the hydrogen generation occurred at the steel as expected. In this case the bond zone between galvanized steel and concrete matrix is not disturbed. From the amount of charge again the inhibiting effect of the chromate can identified. For the specimens with chromate containing cements the amount of charge is considerably lower than those for chromate reduced cements. The difference between the cement types CEM I and CEM II is again pronounced while for CEM III only insignificant differences were observed.

The evaluation of the pull-out tests have shown that for the chromate reduced cements CEM I and CEM II clearly detectable disturbances of the bond zone occur. For a displacement path of 0.01 mm a significant decrease of the bond stress was found. For CEM III the differences are considerably smaller. The obtained results show a good

correlation with the electrochemical measurements. After a testing time of 28 days the differences noticeably decrease. For displacement paths of 0.5 mm a significant influence of the measuring results due to the chromate content is no longer visible. Here, the compressive strength of the concrete matrix is predominantly important.

The results have clearly proven that the chromate reduction for cement types CEM I and CEM II adversely affects the bond zone. Depending on the initial chromate content in the Portland cement clinker for CEM III it can be assumed that a further reduction of the chromate content will not lead to a considerable change of the bond zone.