SUMMARY

The subsequent reinforcement of existing concrete structures with steel- or CFRP- plates (CFK) is a well-established reinforcement method. The reinforcement is realised by using glued on plates in the area of the longitudinal bending force of beams or ceiling panels as the result of the field or bearing moment. The glued on plates assimilate only tensile forces. With the CFRP-plates the ordinary reinforcement of the pressure zone is not possible [6].

At the beginning of this strengthening methods Steel plates were used. As a result of their huge empty weight and manageability, the length of the plates is constrained to a length of 8 m. Thus, it reduces the field of application. Compared to this, the CFRP-plates exhibit a lower empty weight and they are easier to handle.

In the current German standards the end of the steel- or CFRP- plates have to be protected against plate debonding (LEK) with external enclosures of steel or CF-sheets. The positive effect of the enclosures against plate debonding is well known, but not verified exactly. It depends on the material (steel or CF-sheet), the stiffness as a result of the thickness of the enclosure as well as the geometric rates between the plate b_l and the beam b_w. The increase of the bond capacity as the result of the enclosures arises after passing the maximum bond capacity $F_{l,max}$. The bond capacity $F_{l,max}$ is the maximum bond capacity which can be transmitted without any enclosures. The aim of the research project is the development of a model which describes the increase of the bond capacity $\Delta F_{l,1}$ (fig. 1.3), depending on the type and stiffness of enclosure (steel, CF-sheet), the concrete quality as well as the geometric rates between the plate and beam.

The results of this work, which describes the behaviour of enclosures to the bond capacity, will be used for the calculation of the tractive force of the steel or CFRP-plates. Te aim is to investigate under what terms shear stirrups over the complete reinforcement can be included, into the dimensioning of the reinforced beam. Especially shear stirrups in the middle of the field of a beam can improve the bearing capacity as the result of obstruction of plate debonding. Hence ,it leads to a more economic design of the beam with steel or CFRP-plates.

Furthermore, a better acknowledgement of the existing reserve of the bearing load culminate in a maximum utilisation of the load capacity, because of the external enclosures at the end of the plates. This leads to a higher acceptable design moment in reinforcement of concrete structures.

Chapter 1 of this work gives a short introduction to the mechanical behaviour and the increase of the bond capacity of subsequent applied plates in addition to external enclosures. The mechanism of the rising bearing load, as a result of the self-induced contact pressure, is explained and from this the aim as well as the problems of the research project.

In **Chapter 2** the difference in the bond behaviour of subsequent applied plates and inner reinforcement is shown. The difference in force transfer by intact bond and bond failure of the reinforcement to the concrete is explained. In the past several models were developed to describe the bond behaviour. The linear analysis, based on the bilinear analysis, determines the feasible valuation. With this bond law and the differential equation of the sliding bond, it is possible to describe at every point of the bond length the displacement, the shear- and normal stress in the plate. In this chapter the bond law as well as the differential equation of the sliding bond are exemplified.

Moreover the origin and the effectiveness of contact pressure has to be investigated. Basically you have to distinguish between the active and self-induced contact pressure. Both of them produce a increase of the plate force, which was detected in the past, but not exactly reproduced based on the proper parameters. Out of this, it is necessary to investigate systematically the origin of the self-induced contact pressure depending on different enclosure materials (steel, CF-sheet), the different stiffness of the enclosure as well as the geometric rates between the plates and beams.

In **Chapter 3** the experimental tests and the results are shown. All together three different test series were made.

In the first series the crack opening obstruction of the different enclosure types (steel, CF-sheet) is investigated by using pullout tests. With these tests, it is possible to describe the crack opening obstruction or rather the self-induced contact pressure based on the crack opening. The following tests detected the correlation between the bond capacity and the self-induced contact pressure. In the third series the total bond force in relation to the external enclosure was investigated with dimensioned test specimens which are used in practice. These test results are used to verify the developed design model.

In **Chapter 4** the model is shown to exemplify the force transfer in a crack. There are several different models in the literature, which all describe the force transfer in diagonal proceeding shear cracks of concrete structures. The problem of the diagonal proceeding shear cracks can also be transferred to the horizontal crack zone by plate debonding. This is acceptable because the force in a diagonal proceeding crack can be divided into a horizontal and vertical force couple. For further investigation, the model of Walraven is selected to describe and calculate the force transfer.

Chapter 5 shows the algorithm for the calculation of the load increase due to the enclosure. Basically there is a difference between steel- and CF-sheets. Depending on the different geometrical rates between plate and concrete as well as material and stiffness of the enclosure, the algorithms for calculating the passive contact pressure were developed first. The algorithms can also represent parameter combinations which were not explicit determined by the experiment.

The calculation of the increase of the plate tensile force due to contact pressure then followed. The increase of the plate tensile force is caused by a higher shear bearing capacity parallel to the bond crack joint which results from the normal stress perpendicular to the bond crack joint. Algorithms for this are also introduced which describe the dependence of the shear bearing capacity and the active normal stress.

Afterwards it was shown that the previously developed approach can be used on structural members with realistic enclosures to determine the experimental plate tensile forces. The developed design is not only valid for the experimentally researched parameter combinations but also for other parameters of geometrical rates between plate and beam, stiffness as well as material of the enclosure.

In **Chapter 6** the simplified design was developed, where parameters with insignificantly small effect on the load increase of the plate tensile force stay unconsidered. The qualitative effect on the load increase of the plate tensile force is reviewed and defined. However, even the simplified design for enclosure with steel and CF-sheets differs fundamentally.

In contrast to the performed tactile experiment in **Chapter 7,** in the experimental structural members introduced in Chapter 3 with realistic enclosures, only the uniaxial stress condition in the glue joint between lamella and enclosure was considered, because within the research project only the load increase of the lamella tensile force due to passive contact pressure was researched. In the experiment this was carried out by a sliding joint between the enclosure and the lamella. With conventional stirrup like enclosures, however, there is a biaxial stress condition in the glue joint since the lamella is glued together with the enclosure.

Within these tactile experiments, the effect of the actual biaxial stress condition was reviewed for selected parameters and qualitatively evaluated. The experiments show the need to research further more into effective and more economical designs. With those experiments in the future not all parameters will have to be considered. In Chapter°7 approaches and ideas for necessary experiments are mapped.

In **Chapter 8** the developed results are summed up and ideas and hints for continuing research projects are expressed.