Prestressing Systems for Structural Strengthening with Sika\textsuperscript{®} CarboDur\textsuperscript{®} CFRP Plates
Prestress – Applying forces to a structure to deform it in such a way that it will withstand its working loads more effectively or with less total deflection. (Post-tensioning is a method of prestressing a poured in place concrete structure after the concrete has hardened.)

Advantages of Prestressed Sika® CarboDur® CFRP Plates

As compared to Prestressing Steel

- Easy prestressing of existing structures
- Lower weight for easy handling
- Lower loss of prestress due to higher initial tensile strain
- Compact because of thinner section
- Comparable stress level to much heavier prestressing steel
- No stress corrosion risk
- Corrosion resistant tendons
- Bonded or non-bonded possibilities

As compared to Sika® CarboDur® CFRP Plates applied without Pretensioning

- Optimal use of the high tensile strengths of the Sika® CarboDur® CFRP plates
- 30% to 50% less plates needed
- Optimal cost/performance ratio
- Increased durability with reduction of crack width and tensile steel strain
- No corrosion risk
- Strengthening effect can also be “appropriate” for dead and permanent load
- Reduction of tensile strain of existing steel reinforcement
- Strengthening of coupling joints of prestressed reinforced concrete bridges
- Possibility of structural strengthening at low substrate temperatures and high humidity without expensive additional precautions (enclosure, heat etc.)
- Low plate thickness up to only 2.4 mm
- Only short end-anchors required

Longitudinal and transverse strengthening of bridges
- Seismic strengthening of masonry and concrete walls
- Strengthening of industrial and commercial buildings
- Strengthening in all climatic conditions
- Increased durability

Sika® Prestressing Systems for Sika® CarboDur® CFRP Plates

Manufacturing of CFRP plate tendons

Plate can be cut from the roll ready for use, not necessary to keep ready-made tendons in stock

Anchor

The tensioning anchor can be placed anywhere on the plate. Flat anchor plate.

Force transfer

Prestressing force transfer in a manner that is appropriate to concrete through the surface of the base plate bonded and bolted onto the concrete

Recess in the concrete

Base plate for force transfer, tensioning plate for hydraulic jack and levelling aid are all placed in a cutout in the concrete or bolted on the concrete surface

Tensioning procedure

Tensioning in two operations, change over or bolted on the concrete surface

Quality control

Quality control on site

Bond

Can be used bonded or non-bonded. Anchorage zone of SLC II always bonded

Handling

Easy for site use due to low weight of temporary aluminium components

Plate

Sika® CarboDur® V614 Plate cross-section 90 × 1.4 mm

Sika® CarboDur® S624 Plate cross-section 60 × 2.4 mm

Tensioning force

Tensioning force 170 – 200 kN depending on type of anchorage

Tensioning force 220 kN

Minimum ultimate load

Plate failure before anchorage failure according to ETAG 013

300 kN

Costs

Low manufacturing and application costs

Low application costs

Efficiency

Quick installation: Application of approx. 10 tendons per team and jack per day

Quick installation: Application of approx. 10 – 15 tendons per team and jack per day

Patents

Patents: “Method and strip-shaped tensile member for strengthening and/or reinforcing reinforced concrete supporting structures and device for carrying out said method.” (DE 198 49 605 A1)


Tests

First tests: EMPA 1999, ETHZ 2000

First tests: EMPA 1998, static load test, fatigue test, load transfer test: ETAG 013

Approvals

DB/ Approval in Germany expected in September 2004

Approval in Switzerland (ASTRA, SBB) expected end of 2004
**Sika® Prestressing Systems**

**Sika® LEOBA CarboDur® SLC II**

**System Components**

- **Sika® CarboDur® CFRP Plate**
  - **Sika® CarboDur® plate: V914**
  - Cross-section: 126 mm²
  - Tensioning force: 170 – 200 kN
  - Pretensioning strain: 8.0 – 9.5 ‰
  - Prestressing loss: 0 % (with approx. 10 % overstressing)
  - Tensioning anchor: LEOBA SLC II

**Adhesive**

- **Sikadur®-30**

**Preparation**

- Take the necessary dimensions and check the condition of the structure to be strengthened
- Determine the anchorage points on the basis of geometry and position of reinforcement
- Repairs and crack injection if necessary

**Application Procedure SLC/Sika® StressHead**

**Tensioning (within open time of adhesive)**

- Install tensioning anchor
- Apply tension with hydraulic jack. Prestressing force verified via jack pressure and elongation of CFRP plate
- Fix the anchorage by means of the locking nuts, remove jack

**Finishing**

- Reprove if necessary
- Blend the protruding end from the mechanically secured bonded plate to serve as back-up anchorage
- Apply coating if necessary

---

**Sika® StressHead**

**System Components**

- **Sika® CarboDur® CFRP Plate**
  - **Sika® CarboDur® plate: S 624**
  - Cross-section: 144 mm²
  - Tensioning force: 220 kN
  - Pretensioning strain: 9.5 ‰
  - Prestressing loss: < 0.1 ‰
  - Tensioning head: StressHead-220

**Adhesive**

- **Sikadur®-30**

**Prepare tendons (plate and tensioning head) to specified length in the factory**

- Factory test of tendon with a 10% higher load (P₀ +10%) as part of quality control on request
- No substrate preparation when applying non-bonded plates
- Drill holes for anchorage (only one core per anchor)
- Fix anchor
- Plate application with Sikadur®-30 or install plate with protective duct

**Movable type III**

- Fix type III

**Movable type I**

- Fix type I

**Movable/Fix type II**

**Movable/Fix type III**

**Movable/Fix type IV**

**Movable/Fix type V**

**Anchors**

- Hydraulic Jack

**Install anchorage**

- Where required install anchor cover or coat the plate
International Case Studies

Prestressing with Sika CarboDur CFRP Plates

Structure

Körschtal Bridge near Stuttgart (D). Longitudinal and transverse prestressed double T cross-sections with two coupling joints.

Problem

Cracks in the coupling joints, risk of failure due to fatigue of longitudinal tendons.

Sika Solution

Injection of the cracks with Sika injection resin. Structural integrity restored by prestressing with Sika® LEOBACarboDur® SLC II system in every coupling joint.

Structure

Neckar Highway Bridge near Heilbronn (D). The prestressed concrete bridge was built in 1964. It was built in sections with the 14 coupling joint sections having 42 coupled internal tendons, double T-beam section.

Problem

Cracks at the coupling joints were observed. Rehabilitation of all the 14 coupling joints was essential.

Sika Solution

Injection of the cracks with Sika injection resin. Structural integrity restored by post-tensioning with 6 Sika® LEOBACarboDur® SLC II systems (total force = 1350 kN) every coupling joint.

Structure

Prestressed single span bridge in Ravenna (Italy).

Problem

A truck damaged the existing prestressing steel cables in an accident. A loss of prestressing occurred and the load capacity of the bridge had decreased.

Sika Solution

With four Sika® LEOBACarboDur® tendons, the initial prestressing situation could be re-established. The length of each tendon was 30 m.

Structure

The Escherkanal Bridge on the Zurich to Chur motorway (CH), built in the fifties, had to be strengthened and refurbished.

Problem

The bridge deck slab over the box girder was very thin and had insufficient reinforcement compared to modern standards, which had led to longitudinal cracking.

Sika Solution

In 2002, the bridge deck slab was prestressed transversely using the Sika® StressHead System. Because of the factory produced tendons, operations inside the box girder turned out to be particularly easy.

Structure

The Escherkanal Bridge near Stuttgart (D). Longitudinal and transverse prestressed concrete box beams with a total length of 155 m (511 ft) and 131 m (430 ft) respectively, had to be rehabilitated.

Problem

Live load test and detailed inspection revealed a number of deteriorated tendons for each beam. The reason for the damages was poor drainage, which led to corrosion of the prestressed steel tendons and spalling of concrete.

Sika Solution

One Sika® StressHead system could replace two deteriorated steel strands on each beam.

Structure

Car manufacturing plant, Győr (Hungary). Post-tensioning of an existing concrete base.

Problem

A building which had been used for logistics was to be converted into a production area with new machinery etc. The existing concrete slab was divided into several sections by construction/daywork joints and would be inadequate for the new loadings to be imposed.

Sika Solution

Securing of several base sections together using prestressed Sika® CarboDur® CFRP plates, with Sika® StressHead system, to produce a united base without joints.

Sika® LEOBACarboDur® SLC II System – Additional References

Bank in Langen near Frösatal (D)

Bridge over the river Lauter near Gemmingen, Baden-Württemberg (D)

"First" highrise building, Frankfurt (D)

Sika® StressHead System – Additional References

Trade Building Amsterdam (NL)

Lucerne Police Headquarters (CH)

Sung San Bridge Seoul, Korea

6 1 7
Technical Summary: Tests performed at the Swiss Federal Laboratories for Materials Testing and Research EMPA (Deuring M., 1993) revealed a potential problem of anchoring the ends of prestressed plates. Under load the plates could debond like a “zipper” from the ends by exceeding the concrete’s tensile strength. It is therefore necessary to hold the ends of a tensioned CFRP plate by means of an anchor head.

To solve this problem, Sika has developed and provides these two systems: Sika® LEOBA CarboDur® SLC II and Sika® StressHead.

<table>
<thead>
<tr>
<th>System</th>
<th>Sika® SLC II</th>
<th>Sika® StressHead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sika® CarboDur® CFRP Plate</td>
<td>V914</td>
<td>S624</td>
</tr>
<tr>
<td>Cross-section</td>
<td>126 mm²</td>
<td>144 mm²</td>
</tr>
<tr>
<td>Tensioning force</td>
<td>170 – 200 kN</td>
<td>220 kN</td>
</tr>
<tr>
<td>Pretensioning strain</td>
<td>8.0 – 9.5 ‰</td>
<td>9.5 ‰</td>
</tr>
<tr>
<td>Prestressing loss</td>
<td>0 ‰ (SLC with approx. 10 % overstressing)</td>
<td>&lt; 0.1 ‰</td>
</tr>
<tr>
<td>Tensioning anchor</td>
<td>LEOBA SLC II</td>
<td>StressHead-220</td>
</tr>
</tbody>
</table>

Test according to ETAG 013

Instructions for assessment of the durability of prestressing

Federal Highway Agency, BAST (D)

Bending moment

With prestressed Sika® CarboDur® at 800 kN

Without strengthening

\[ M_0 = 10.35 \text{ MNm} \]

\[ \Delta M_{\text{r}} = 56 \text{ N/mm}^2 \]

\[ \Delta M_{\text{r}} = 132 \text{ N/mm}^2 \]

\[ 0.5 \max M_y = 3.27 \text{ MNm} \]

\[ 0.5 \max M_y = 3.75 \text{ MNm} \]

\[ \Delta \sigma_{\text{r}} = 56 \text{ N/mm}^2 \]

\[ \Delta \sigma_{\text{r}} = 132 \text{ N/mm}^2 \]

\[ -M_{\text{r}} 0.7 V = 400 \]

\[ 500 \]

\[ 600 \]

\[ \sigma_{\text{r}} = \frac{M_0}{W_0} \]

\[ \sigma_{\text{r}} = \frac{\Delta M_{\text{r}}}{W_0} \]

\[ \sigma_{\text{r}} = 110 \text{ N/mm}^2 \]

Initial moment \( M_0 = M_{\text{decompression}} \) for 70 % \( V_\infty \) + \( M_T = 12K \)

Allowed \( \Delta \sigma_{\text{r}} \leq 110 \text{ N/mm}^2 \)

Also available from Sika

Sika Services AG
Corporate Construction
CH-8048 Zürich
Switzerland
Phone +41 44 436 40 40
Fax +41 44 436 46 86
www.sika-construction.com

Also available from Sika

Your local Sika Company

Our most current General Sales Conditions shall apply. Please consult the Product Data Sheet prior to any use and processing.