Prestressing Systems for Structural Strengthening with Sika® CarboDur® CFRP Plates
Prestressing – 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.)

Principles of Sika® CarboDur® Prestressing Systems

A prestressed Sika® CarboDur® CFRP plate combines the advantages of bonded Sika® CarboDur® CFRP plate strengthening with those of conventional prestressing. The Sika® CarboDur® CFRP plate applies compressive stress in the tensile zone of the cross-section, thus reducing tensile stress in steel reinforcements under service load, and consequently crack width and deflection will be reduced. For calculation of the load-bearing capacity, the tensile force in the prestressed Sika® CarboDur® CFRP plate is added to the tensile strength of the steel.

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

Advantages of Sika® CarboDur® CFRP Plates

- 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
- Anchorage of plate in carbon fiber (non-metallic) anchor head, without adhesive
- Concentrated force transfer into the substrate, adaptable to structural conditions, independent from local concrete surface properties
- No need for a recess in the concrete
- Ready-made plate delivered to site

Tensioning procedure

- Tensioning in two operations, change over or bolted on the concrete surface
- Longitudinal and transverse strengthening of bridges
- Strengthening of coupling joints of prestressed reinforced concrete bridges
- Possibility of structural strengthening at low substrate temperatures and high humidity without expensive additional precautions
- Low plate thickness up to only 2.4 mm
- Only short end-anchors required

Quality control

- Quality control on site
- Quality control in the factory during manufacturing of the tendons
- Anchorage of plate in carbon fiber (non-metallic) anchor head, without adhesive
- Appropriate for site use due to adaptable anchorage possibilities
- Anchorage zone of SLC II always bonded

Handling

- Easy for site use due to low weight of temporary aluminum components
- Can be used bonded or non-bonded (for instance at low substrate temperatures or high humidities)
- Plate failure before anchorage failure according to ETAG 013
- Tensioning force 220 kN

Tensioning force

- Tensioning force 170 – 200 kN depending on type of anchorage
- Tensioning force 170 – 200 kN depending on type of anchorage
- Tensioning force 220 kN
- Plate cross-section 90 x 1.4 mm
- Plate cross-section 60 x 2.4 mm

Minimum ultimate load

- Plate failure before anchorage failure according to ETAG 013
- 300 kN
- Low manufacturing and application costs
- Low application costs

Costs

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

Tests

- First tests: EMPA 1998, static load test, fatigue test, load transfer test: ETAG 013
- First tests: EMPA 1999, ETHZ 2000

Approvals

- DIBt 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**
- **Adhesive**
  - Sikadur®-30

**LeoBA SLC II**

- **Anchors**
- **Hydraulic Jack**
- **Adhesive**
  - Sikadur®-30

**Sika® CarboDur® CFRP Plate**
- Cross-section: 126 mm²
- Tensioning force: 170 – 200 kN
- Pretensioning strain: 8.0 – 9.5 ‰
- Prestressing loss: 0 %
- Tensioning anchor: LEOBA SLC II

**Application Procedure SLC/Sika StressHead**

**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.

**Tensioning (within open time of adhesive)**
- 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**
- Reprofile if necessary.
- Where required install anchor cover or coat the plate.

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**Sika® StressHead**

**System Components**
- **Adhesive**
  - Sikadur®-30

**LeoBA SLC II**

- **Anchors**
- **Hydraulic Jack**
- **Adhesive**
  - Sikadur®-30

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

**Application Procedure SLC/Sika StressHead**

**Preparation**
- Prepare tendons (plate and tensioning head) to specified length in the factory.
- Factory test of tendon with a 10% higher load (P₁₀ =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.

**Tensioning (within open time of adhesive)**
- Install tendon in anchorage.

**Finishing**
- Reprofile if necessary.
- Where required install anchor cover or coat the plate.
International Case Studies

Prestressing with Sika® CarboDur® CFRP Plates

Structure
Kirschtal 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 by fatigue of longitudinal tendons.

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

Structure
Backeberg Bridge near Flensburg (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 5 Sika® LEOBA CarboDur® 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® LEOBA CarboDur® 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 1960s, 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
Körschtal Bridge near Stuttgart (D). The bridge deck slab over the box girder was very thin and had led to longitudinal cracking.

Problem
Pre-tensioned double T cross-sections with two coupling joints.

Sika Solution
In 2002, the Escherkanal Bridge was refurbished. The bridge deck slab over the box girder was very thin and had led to longitudinal cracking.

Structure
Post-tensioning of an existing concrete base.

Problem
Deteriorated cables for each beam. The reason for the damages was poor drainage, which led to corrosion of the prestressed 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)

Problem
A building which had been used for logistics was to be converted into a production area with new machinery etc. The existing concrete base 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.

Structure
Fina highrise building, Frankfurt (D)

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

Sika® StressHead System – Additional References

Trade Building Amsterdam (NL)

Lucombe Police Headquarters (CH)

Sung San Bridge Seoul, Korea


Sika® LEOBACarboDur® SLC II System – Additional References

Bank in Langen near Frankfurt (D)

Bunz in Lauden near Freiburg (D)

“Fina” highrise building, Frankfurt (D)
Prestressing Systems with Sika® CarboDur® CFRP Plates

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.

### System Specifications

<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

Bending moment

- With prestressed Sika® CarboDur® at 800 kN
- Without strengthening

- $M_0 = 10.35 \text{ MNm}$
- $0.5 \max M_p = 3.27 \text{ MNm}$
- $0.5 \max M_p = 3.75 \text{ MNm}$

Stress in the reinforcement $\sigma_2$

Initial moment $M_0 = M_{\text{decompression}}$ for 70 % $V_\infty + M_{T=12K}$

Allowed $\Delta \sigma_2 \leq 110 \text{ N/mm}^2$

### Also available from Sika

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