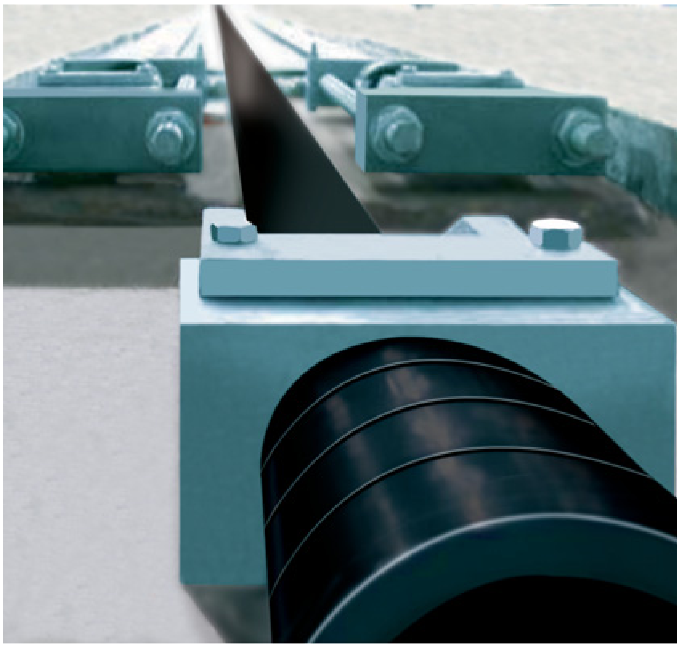
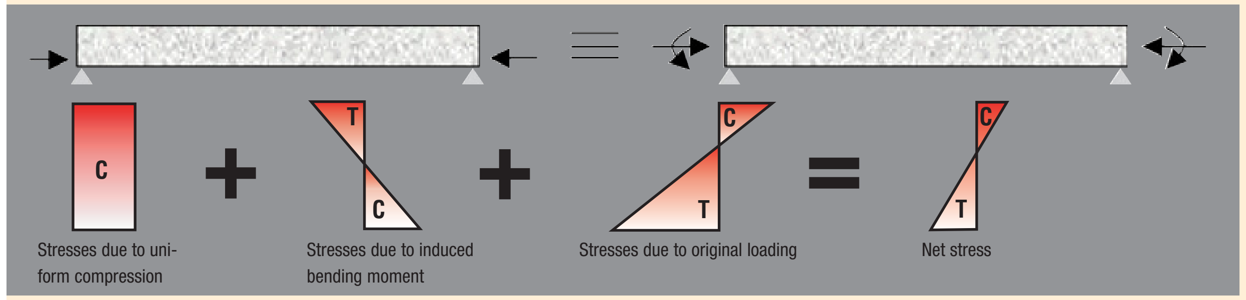
Construction



Prestressing Systems for Structural Strengthening with Sika® CarboDur® CFRP Plates

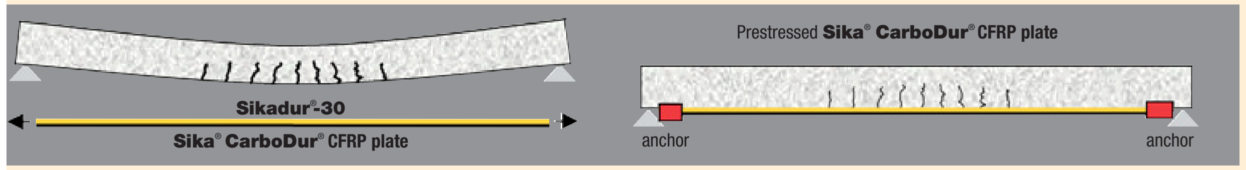
The Concept of Prestressing

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

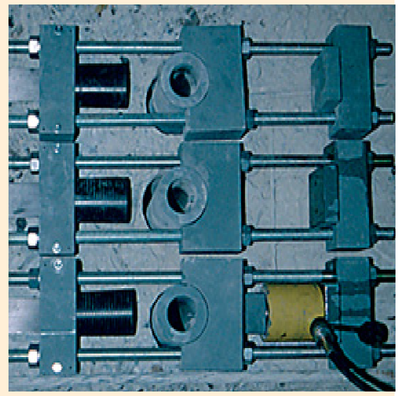
- Easy prestressing of existing structures
- Lower weight for easy handling
- Lower loss of prestress due to higher initial tensile strain
- Compact because of thinner section
- Comparable stress level to much heavier prestressing steel
- No stress corrosion risk
- Corrosion resistant tendons
- Bonded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

- **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



	Sika® LEOBA CarboDur® SLC II	Sika® StressHead
Manufacturing of CFRP plate tendons	Plate can be cut from the roll ready for use, not necessary to keep ready-made tendons in stock	Ready-made plate delivered to site
Anchor	The tensioning anchor can be placed anywhere on the plate. Flat anchor plate	Anchorage of plate in carbon fiber (non-metallic) anchor head, without adhesive
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	Concentrated force transfer into the substrate, adaptable to structural conditions. Independent from local concrete surface properties
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	No need for a recess in the concrete
Tensioning procedure	Tensioning in two operations, change over from temporary to permanent anchorage	Short installation time, tensioning in one operation
Quality control	Quality control on site	Quality control in the factory during manufacturing of the tendons
Bond	Can be used bonded or non-bonded. Anchorage zone of **SLC II** always bonded	Can be used bonded or non-bonded (for instance at low substrate temperatures or high humidities)
Handling	Easy for site use due to low weight of temporary aluminium components	Appropriate for site use due to adaptable anchorage possibilities
Plate	**Sika® CarboDur® V914** 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 tensional member for strengthening and/or restoring reinforced or prestressed concrete supporting structures and device for carrying out said method." (DE 198 49 605 A1)	Patents: "Reinforcement device for supporting structures" (EP-Patent N° 1007809).
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

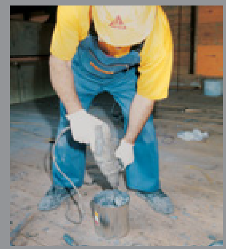
Sika® Prestressing Systems

Sika® LEOBA CarboDur® SLC II

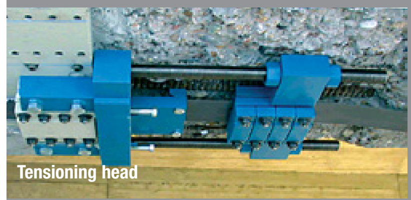
System Components
Sika® CarboDur® CFRP Plate

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**

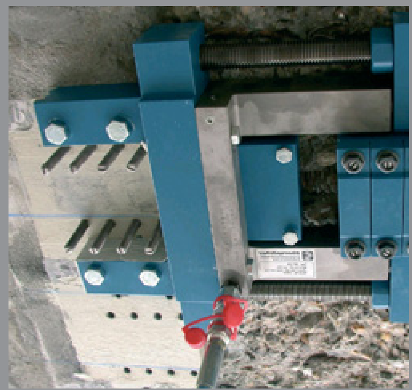
Adhesive
Sikadur®-30



Anchors



Hydraulic Jack



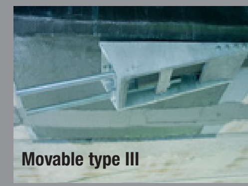
Sika® StressHead

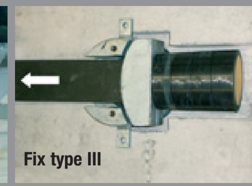
System Components
Sika® CarboDur® CFRP Plate

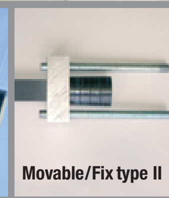
Sika® CarboDur® plate: S 624
Cross-section: 144 mm²
Tensioning force: 220 kN
Pretensioning strain: 9.5 ‰
Prestressing loss: < 0.1 ‰
Tensioning head: **StressHead-220**

Adhesive
Sikadur®-30

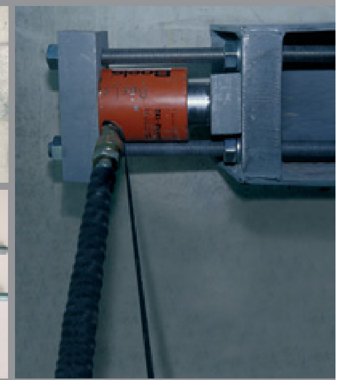
Anchors







Hydraulic Jack



Application Procedure SLC/ Sika® StressHead

Preparation

Common steps:
- 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

Sika® LEOBA CarboDur® SLC
- Security: Plate failure before anchorage failure (tested up to 365 kN)
- Substrate preparation only in anchorage zone. Substrate preparation for bonded application according to conditions
- Set dowels for base plate
- Install base plate with bolts and **Sikadur®-30** adhesive
- Plate application as for non-tensioned plate with **Sikadur®-30**

Sika® StressHead
- Prepare tendons (plate and tensioning head) to specified length in the factory
- Factory test of tendon with a 10 % higher load (P_0 +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)

Sika® LEOBA CarboDur® SLC
- Install tensioning anchor

Sika® StressHead
- Install tendon in anchorage

Common steps:
- 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

Sika® LEOBA CarboDur® SLC
- Install end anchorage
- Transfer prestressing force after hardening of the adhesive from tensioning anchor to the end-anchorage

Finishing

Sika® LEOBA CarboDur® SLC
- Reprofile
- Bond the protruding end from the mechanically secured bonded plate to serve as back-up anchorage
- Apply coating if necessary

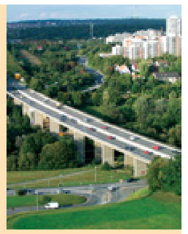
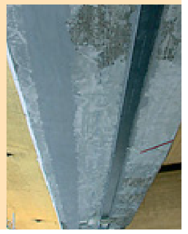
Sika® StressHead
- Reprofile if necessary
- Where required install anchor cover or coat the plate

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 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.

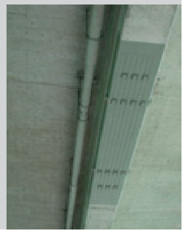




Structure
Neckar Highway Bridge near Heilbronn (D). The prestressed concrete bridge was built in 1964. It was built in sections with the 14 coupling joint sections having 42 coupled internal tendons, double T-beam section.

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 9 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.

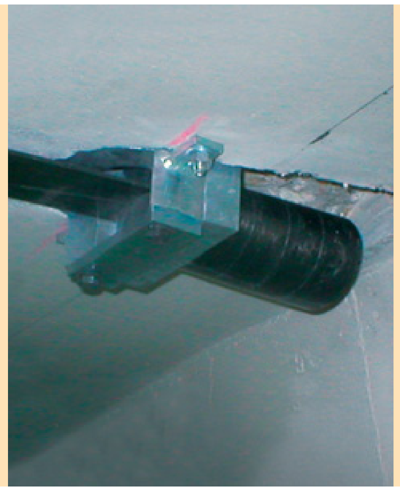
Sika Solution
With four Sika® LEOBA CarboDur® tendons, the initial prestressing situation could be re-established. The length of each tendon was 30 m.



Structure
The Escherkanal Bridge on the Zurich to Chur motorway (CH), built in the 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.

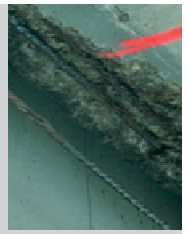
Sika Solution
In 2002, the bridge deck slab was prestressed transversely using the Sika® StressHead System. Because of the factory produced tendons, operations inside the box girder turned out to be particularly easy.



Structure
The **Clinton & Hopkins Bridges**, Defiance County, Ohio. Both six span, precast, prestressed concrete box beams with a total length of 155 m (511 ft.) and 131 m (430 ft.) respectively, had to be refurbished.

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

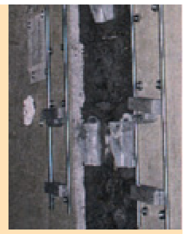
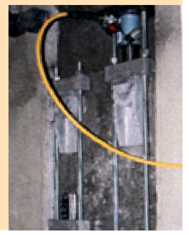
Sika Solution
One Sika® StressHead system could replace two deteriorated steel strands on each beam.


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

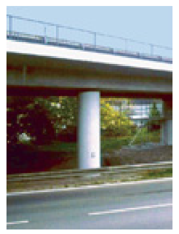
Problem
A building which had been used for logistics was to be converted into a production area with new machinery etc. The existing concrete slab was divided into several sections by construction/daywork joints and would be inadequate for the new loadings to be imposed.

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.

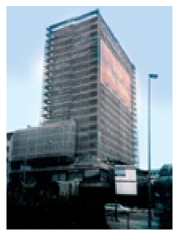




Sika® LEOBA SLC System – Additional References


Bank in Langen near Frankfurt (D)



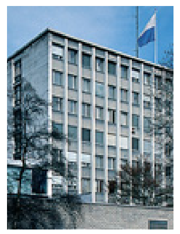
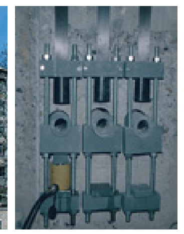

Bridge over the river Lauter near Gomadingen, Baden-Württemberg (D)



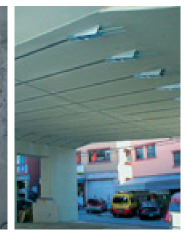

"Fina" highrise building, Frankfurt (D)

Sika® StressHead System – Additional References


Trade Building Amsterdam (NL)

Lucerne Police Headquarters (CH)




Sung San Bridge Seoul, Korea

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1 Deuring M.: "Strengthening of reinforced concrete by means of tensioned composite fiber materials", Dissertation, EMPA Bericht 224, Eidgenössische Materialprüfungs- und Forschungsanstalt Zürich 1993; **2** Maissen A., Czaderski C.: "Testing of tensioned CFRP plates", EMPA Bericht Nr. 172745'/2.1998, Eidgenössische Materialprüfungs- und Forschungsanstalt Zürich 1998; **3** Andrä H.P., Maier M.: "Trend-setting development for structural strengthening and rehabilitation, LEOBA CarboDur surface tendon", IBK-Fachtagung 241. Darmstadt 1999; **4** Andrä H.P., Maier M.: "Post-Strengthening of R/C Structures by means of Prestressed Externally Bonded Carbon Fiber Reinforced Polymer Strips", Conference Proceedings of Structural Faults & Repair 99, Commonwealth Institute London, July 1999; **5** Andrä H.P., Maier M.: "Post-Strengthening with Externally Bonded Prestressed CFRP Strips", Conference Proceedings of 16th Congress of IABSE, Lucerne September. 2000; **6** Andrä H.P., König G., Maier M.: "Tensioned CFRP surface tendons", Beton und Stahlbetonbau Jahrgang 96 (2001) Heft 12, Verlag Ernst & Sohn, Berlin, Seite 737 – 747; **7** Berset T., Schwegler G., 2000: "The use of pre-stressed CFRP-Laminates as post-Strengthening." 16th Congress of IABSE, Lucerne, 2000; **8** Glaus P., Schwegler G., 2001: "Seismic upgrading of masonry building with fiber composites". 20th European Regional Earthquake Engineering Seminar, Sion 2001; **9** StressHead 2001: Prestressing system for CFRP plates", 8.2001; **10** Schwegler G., Glaus P., Berset T.: "Use of tensioned CFRP plates" bonded and tensioned CFRP plate reinforcements, Kolloquium, ETHZ, Zürich, 27. November 2001; **11** Berset T., "Approval and testing of CFRP plate prestressing systems", bonded and tensioned CFRP plate reinforcements, Kolloquium, ETHZ, Zürich, 27. November 2001; **12** Federal roads department ASTRA: "Anchoring of tensioned CFRP plates", IABSE Symposium, Melbourne, September 2002 - tec21, Post-Strengthening of a motorway bridge with prestressed CFRP strips, T. Berset, G. Schwegler, L. Trausch, 2002 - Andrä H.P., König G., Maier M., "First application of CFRP-Tendons in Germany", IABSE Symposium, Melourne, Sept. 2002 - Peters H., "CarboDur Lamellen in Deutschland", Beton- und Stahlbetonbau, Mai 2004 - Andrä H.P., Maier M., Poorbizar M., "Application of FRP-Composites in construction and rehabilitation of structures - CFRP-Composites for a new generation of tendons", Minister of building Conference, Teheran, May 2004 - Schwegler G., Erdbebenschutz durch vorgespannte CFK-Lamellen. Beton- und Stahlbetonbau Heft 5, 2004 - Schwegler G., Berset T.,: Spannsystem für CFK-Lamellen, Schlussbericht zum Forschungsauftrag AGB 1999/155 (83/99), Bundesamt für Strassen (ASTRA), Bern 2004 (under preparation).

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.**

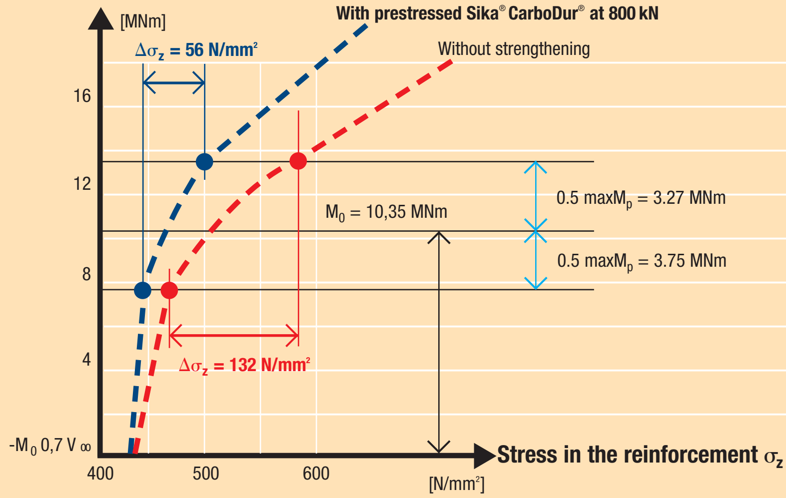
System	Sika® SLC II	Sika® StressHead
Sika® CarboDur® CFRP Plate	**V914**	**S624**
Cross-section	126 mm²	144 mm²
Tensioning force	170 – 200 kN	220 kN
Pretensioning strain	8.0 – 9.5 ‰	9.5 ‰
Prestressing loss	0 ‰ (SLC with approx. 10 % overstressing)	< 0.1‰
Tensioning anchor	**LEOBA SLC II**	**StressHead-220**

Test according to ETAG 013

Instructions for assessment of the durability of prestressing

Federal Highway Agency, BAST (D)

Bending moment



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

Allowed $\Delta\sigma_z \leq 110$ N/mm²

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Switzerland
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