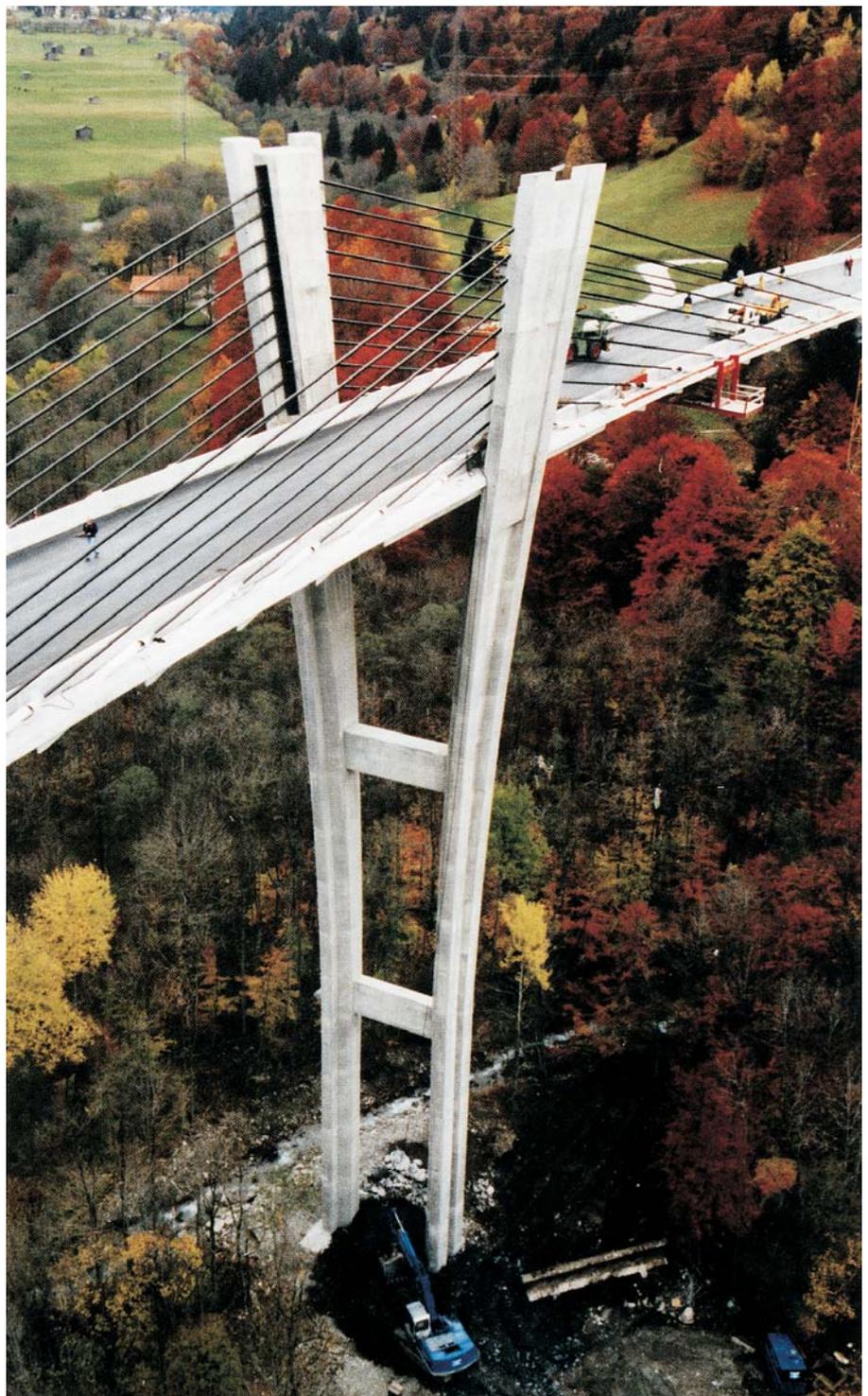


A28a Prättigauerstrasse, By-pass of Klosters:

## Sunnibergbridge completed

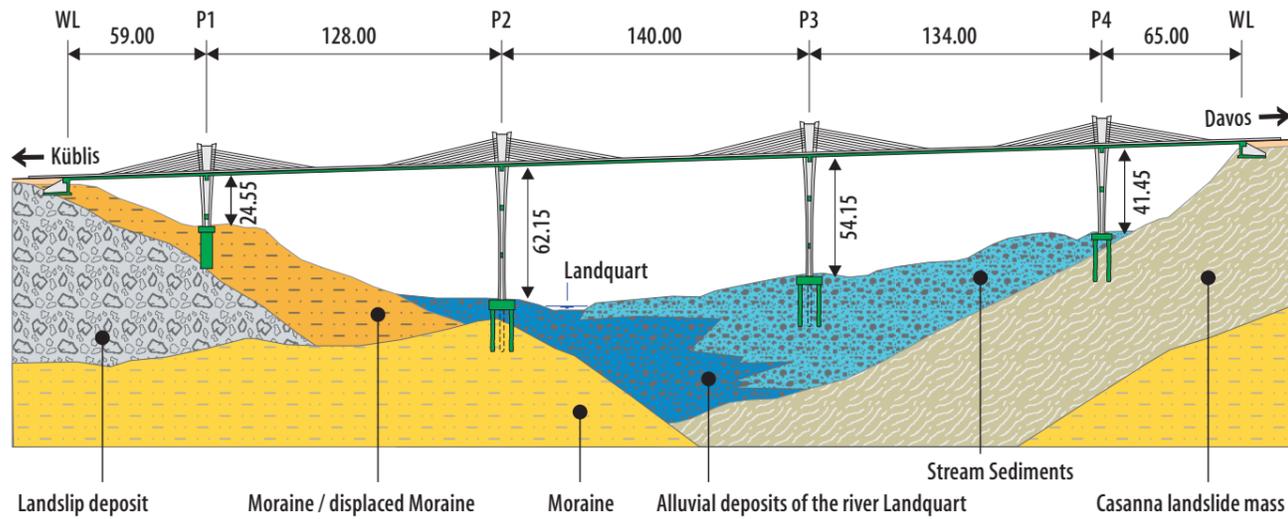
The Sunnibergbridge has been completed after less than two and a half years of construction work. It is the most outstanding construction within the by-pass of the town of Klosters in south-eastern Switzerland. It is now open to traffic, although use will be restricted to construction traffic for the time being. Everyone involved, from the planning engineer to the rebar fixer, can be very proud of this remarkable construction. The 8500 m<sup>3</sup> of concrete seem to span almost weightlessly across the valley. The local population as well as the many visitors from all over the world are overwhelmed by the sheer elegance and lightness of this bridge.

The bridge crosses over the river Landquart at about 60 m height. The five-span cable-stayed bridge, with a length of 526 m, presents the greatest eye catcher of the entire by-pass. Therefore it has to meet highest requirements with respect to aesthetics and blending into the landscape. Further, high requirements were placed on the durability, which is vital in the rough mountain climate. An environmentally friendly construction-procedure was also of importance. The concept of the bridge proves especially convincing through its technical ingenious and intense aesthetics. Yet the bridge is not a dominating feature, but blends perfectly into the environment, which is either covered in forests or cultivated by the local farmers. The bridge is an exciting experience, both, for the onlooker and the user. The by-pass of Klosters has definitely gained a landmark. Innovative design and approved construction-work have created another monument to celebrate the diversity of concrete.



Pier P3 from a bird's-eye view

## 526 m long and 40 cm thick



Elevation with geology

The bridge consists of four towers providing three large main spans and two smaller side spans. Due to the strong curvature in plan ( $R = 503$  m), the bridge deck can be connected monolithically to the abutments at both ends, without the use of expansion joints. This provides almost full longitudinal and lateral support of the piers at the level of the deck. Again this implies that the bending moments in the piers, due to partial loading of the girder, decrease linearly down the piers. The form of the piers reflects the shape of moment within the piers. The pylons above the road are relatively short, considering they measure a mere 14 to 16 m. The pylons are slightly inclined outwards due to clearance requirements of the curved roadway. The piers and the pylons together create a static and formal unity. The alterations in length of the superstructure cause horizontal displacement in lateral direction of the bridge axis. Because of the continually changing views while driving over the bridge, the stay cables are arranged in the shape of a harp, giving as strict and clear a pattern of cables as possible. The girder cross section consists of a slab with relatively slender edge beams. The total construction costs ran at a total of

20 million Swiss Francs. They are approximately 14% higher than the costs for a traditional cantilever constructed girder, which would have been the most economical solution. But considering that the innovative design provides remarkable elegance for this prominent bridge in a sensitive landscape, the increased costs were considered justified.

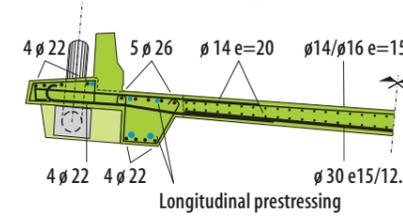


Placement of the pavement on the bridge



## The bridge from the civil engineer's point of view

The calculations of the internal forces were carried out on a three-dimensional girder model with finite beam-elements and linear-elastic material. The geometry of the model axis correspond to the center line of the real system. The bearing conditions were simplified: fixed at the pier head and elastically fixed at the abutments. The deflection forces due to the curvature of the superstructure produce a big lateral bending moment in the lower part of the pylons. On the outside of the curve this bending moment reaches roughly 50 MNm at design level. The moment is transferred through the massive prestressed crossbeam into a pair of normal forces in the two pier legs. At the same level of the pylon the biggest longitudinal bending mo-



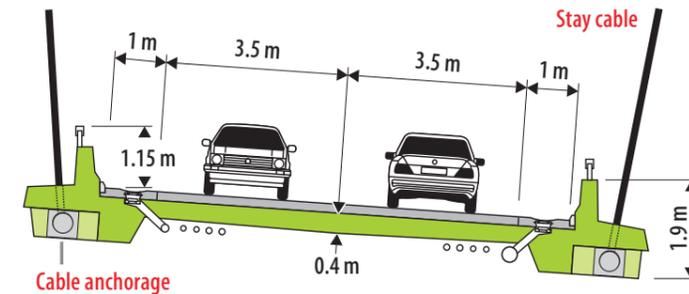
Main reinforcement of the road slab and the edge-beam

ments due to span-wise live load occur. They reach roughly 75 MNm at the design level. These high levels of stresses lead, despite massive prestressing, to reinforcement contents of more than 200 kg/m<sup>2</sup>.

### 235 mm deflection

The vertical deformations due to the span-wise live load provided an essential design criterion. They were li-

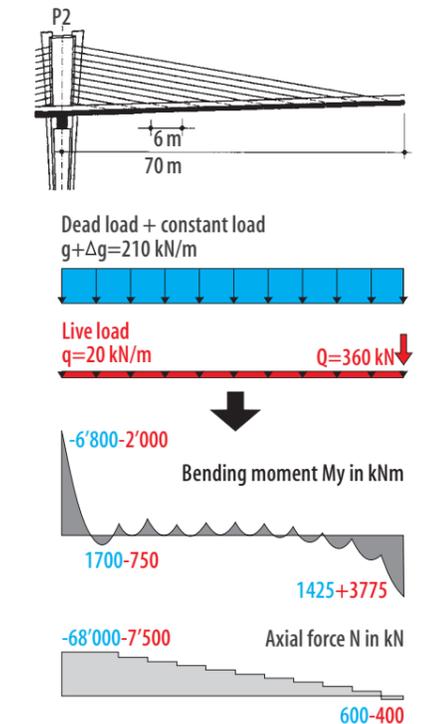
imited to 1/400 of the span. The assumed live load (for deformation control) consists of a uniformly distributed load of 2 kN/m<sup>2</sup> and a concentrated load  $Q$  of 360 kN, which proved to be of great influence. The deformations were determined assuming an uncracked System with a modulus of elasticity of 35'000 N/mm<sup>2</sup>. The vertical displacement of the biggest span of 140 m thus amounts to 235 mm, which corresponds to 1/600 of the span. About 40% of the deformation derives from the rotation of the top of the pylon. The other 60% derive from the elastic extension of the cables. The two neighboring spans display an upward displacement of 60 mm, which is roughly equivalent to 25% of the deformation of the main span.



Cross-section



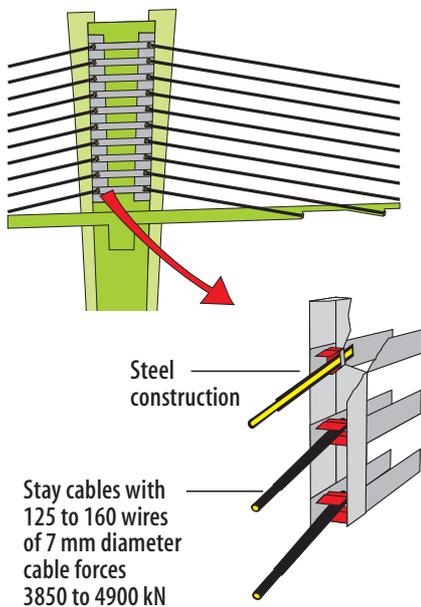
Tightening of the cables with a hydraulic jack



Internal forces in bridge girder

## 6 meters of bridge each week

Exact surveying proved essential to the quality of a delicate structure such as the Sunnibergbridge. A surveyor, who had to maintain a precision of 15 mm, marked out the axis of pylon and bridge. The foreman carried out the final survey at the construction site. Pylon P2, for example, had a deviation of only 13 mm off target at 60 m above ground. The survey work had to be carried out early in the morning. Otherwise the sun's effect on the concrete and the cables could have resulted in deviations up to 40 mm.



Cable anchorage in the pylon

### Main masses:

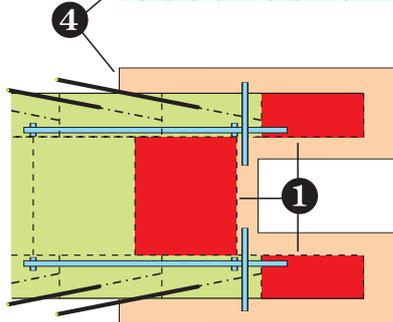
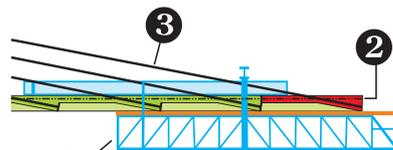
Construction steel	240 tons
Steel for stay cables	320 tons
Prestressing steel	50 tons
Reinforcing steel	1'350 tons
Concrete	8'500 m <sup>3</sup>
Concrete for bored piles	500 m <sup>3</sup>
Formwork	17'500 m <sup>2</sup>

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The pylons have a complex cross-section, which varies according to height. Equally demanding was the formwork on the elegantly curved forms, which was performed in stages of 4 m at a time. The formwork of the piers and pylons basically consisted of 4 rectangular formwork elements with insert pieces for the specific form of the cross-section. The increasing measurements were obtained by shifting the insert pieces.

To achieve greater flexibility and efficiency the contractor decided to produce the concrete with the quality B45/35 in their own plant on site. Micro silicate was added to the concrete for the pylons and the girder to improve the workability and the rapid development of strength. Accordingly the average strength of the concrete was already at 43 N/mm<sup>2</sup> after three days and after 28 days at an incredible 64 N/mm<sup>2</sup>! This reliable and speedy development of strength was an essential factor for the cantilever construction in regular one-week stages.



- 1 Placement of reinforcing steel pouring of concrete of both edge beams and road slab
- 2 Tightening of the longitudinal prestressing in the edge beams
- 3 Placement of the stay cables and tightening between 2100 to 4000 kN
- 4 Shifting of the 37 tons cantilever construction carriage by 6 m to the next construction stage

Cantilever construction



Pier P4 with cantilever construction carriage



Steel construction for cable anchorage in the pylon formwork



Edge-beam with anchorage and reinforcement of the parapets