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Structural Rehabilitation of a Reinforced Concrete and a Prestressed Concrete Bridge

Réhabilitation de la structure de deux ponts, en béton armé et précontraint

Erneuerung einer Stahlbeton- und einer Spannbetonbrücke

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SUMMARY

Two examples of works on reinforced and prestressed concrete bridges are described, each involving different aspects of problems faced by the maintenance programs that the Italian Roadway Board has carried out in recent years. The first case involves an old reinforced concrete bridge whose heavily damaged structures required radical repairs and anti-seismic measures. The second case concerns prestressed concrete span cantilever cables to be inserted in the cross section in order to restore safety margins and correct some of the deflections due to creep.

RÉSUMÉ

Deux exemples de travaux sur des ponts en béton armé et précontraint sont décrits, chacun impliquant différents aspects de problèmes rencontrés par les programmes de maintenance mis sur pied par l'Administration Italienne des Routes. Le premier cas concerne un vieux pont en béton armé dont les importants dommages structuraux ont demandé des réparations essentielles ainsi que des mesures antisismiques. Le deuxième cas concerne le renforcement de travées en porte-à-faux d'un pont en béton précontraint par l'ajout de câbles dans la section transversale, afin de rétablir les marges de sécurité et de corriger une partie des déformations dues au retrait.

ZUSAMMENFASSUNG

Aus dem Unterhaltsprogramm der Italienischen Strassenamtes der letzten Jahren werden beispielhaft zwei Brücken mit unterschiedlichen Problemstellungen beschrieben. Eine alte Stahlbetonbrücke wies so schwere Schäden auf, dass sie radikale Sanierungs- und Erdbebenschutzmassnahmen benötigte. Im zweiten Fall waren in einer Spannbetonbrücke Kragarmvorspannkabel in den Betonquerschnitt einzubauen, um Sicherheitsreserven wiederherzustellen und einen Teil der Kriechdurchbiegung auszugleichen.

1. INTRODUCTION

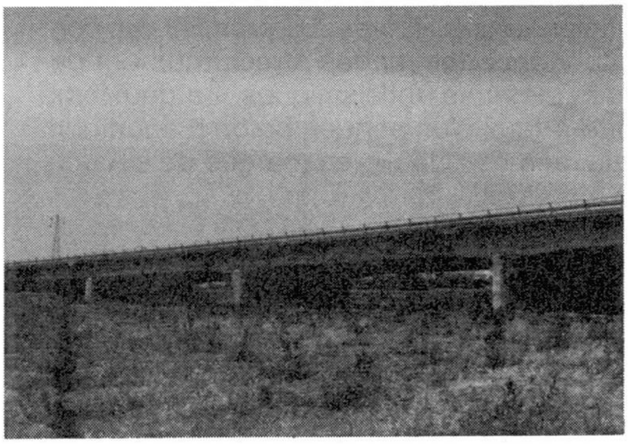
Increased traffic rate and seismic damage in many sites have led to numerous interventions to repair and restore the structures of Italian highways. Deterioration and alteration of materials, deformations caused by creep and need for additional anti-seismic measures give rise to different types of problems. Two examples of strengthening measures are described. The first concerned twin 30-year old reinforced concrete cantilever and Gerber beam bridges on a highway in Southern Italy near the coast. The damage consisted mainly in degradation of the materials with alteration to the concrete, corrosion of uncovered steel bars and low-serviceability of the supports and joints associated with the extreme atmospheric conditions prevailing in the area. The viaducts were subjected to radical repairs (including the demolition of limited portions of the structure) and seismic rehabilitation by accomplishing the longitudinal continuity of the different spans through the elimination of the fixed supports on the piers and all the intermediate joints between the beams and transferring the seismic forces back to special supports constructed behind the abutments. The second example concerned a very long (90 meters) prestressed concrete five-span cantilever bridge that had suffered serious deformations due to creep in the concrete. In order to recover the safety margins of the structure and make it possible to restore the original elevations of the road surface, an additional prestressing cable system was inserted inside the cross section.

THE "GALLICO VIADUCTS"

2.1 Present situation

During the late eighties the Italian National Roadway Board (ANAS) carried out work on some of the viaducts of the Salerno-Reggio Calabria. This section runs through three mountainous regions of Southern Italy where environmental conditions are very severe. Traffic rates have increased heavily since the roads were originally built and it was feared that the present state of conservation of various structural elements was incompatible with the heavy increase in loads. The seismic nature of the area, the particular nature of alterations to materials and the very poor safety margins associated with the isostasy of the structure could have led to brittle collapse under the stress of traffic without warning. A detailed plan of interventions was therefore carried out on some viaducts, for example those known as Fiumara di Gallico and Piana di Gallico, which are near the coast towards the southern end of the Highway (figure 1) in one of the oldest (early sixties) and most threatened parts of the whole structure. The project aimed principally to improve the seismic behavior of the viaducts, adjust the structures to the increased loads and repair the areas, supports and the joints that had become altered. The operation was also intended to reduce the

FIGURE 1



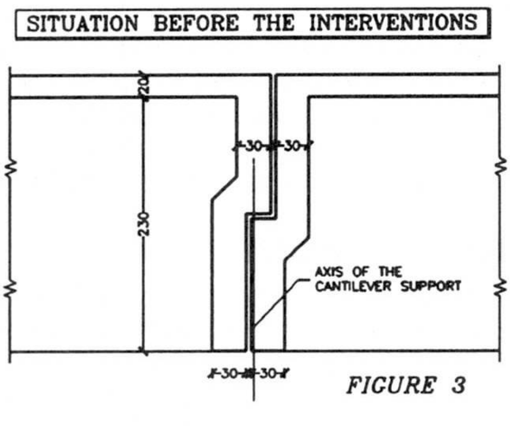
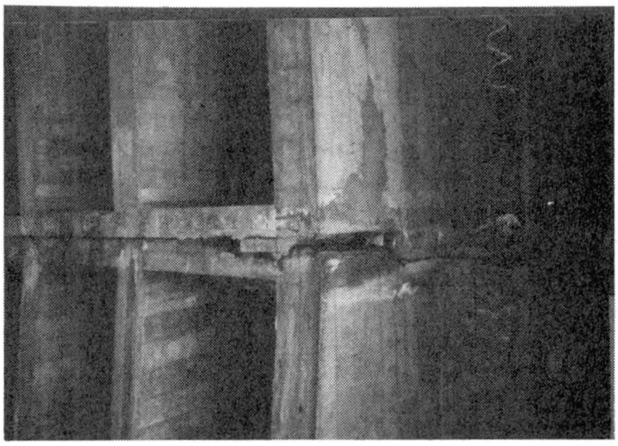


FIGURE 3

maintenance costs for the Board. The two viaducts, each of which has separate decks for each direction of traffic, consist of six 37.4-meter cast-in-place spans, three of which are cantilevered and three consist Gerber beams with 26.6-meter spans supported on six 6-7 meter high piers (photo n. 2). The Gerber beams are supported by very narrow joints girder (figure 3) with four ribs connected by a lower slab for a short distance from the pier along the cantilever.

2.2 Causes of decay and demage

On account of the severe environmental conditions (marine salts in the rain water, wide temperature ranges, heavy traffic) and poor maintenance, the degradation has affected mainly structural elements such as the Gerber joints, in which the steel bars are completely uncovered and deeply corroded



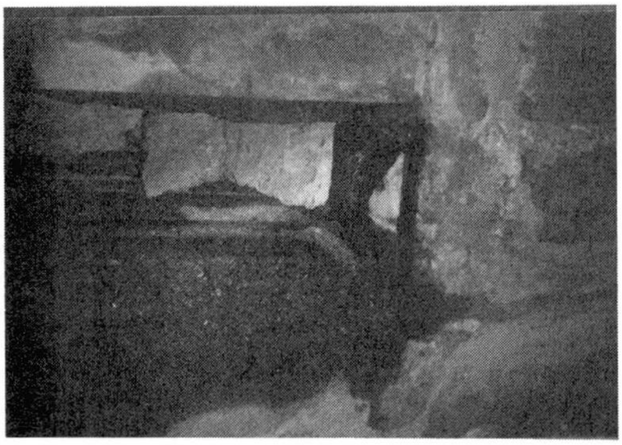


photo 4 - Fiumara di Gallico Viaduct
Gerber joint (lower view)

photo 5 - Fiumara di Gallico
Gerber joint (detail)

(photo n. 4-5). The seat of the supported beams - which is further restricted by degradation - is so reduced as to cast doubt on the stability of the beams. Weathering has also removed the concrete bar covering in many areas of the decks, particularly on the west side, towards the coast. A detailed program of in situ tests (pull-out tests, carbonation tests, microdrilling and sampling of concrete, endoscopic tests, etc.) on the structure was carried out to evaluate the actual state of alteration of the material, their strength and the efficiency of the supports apparatus.

2.3 Intervention criteria

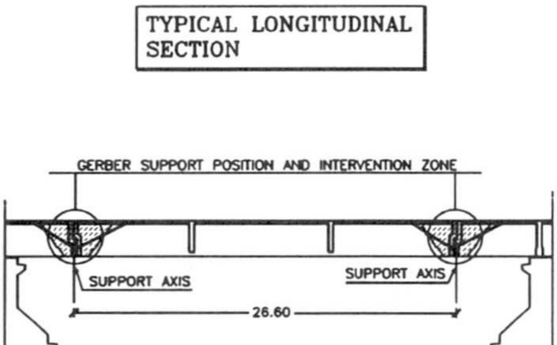


FIGURE 6

The principal objective of the intervention was to improve the seismic behaviour of the structure by creating a continuous kinematic chain between the various spans so as to transfer the horizontal actions to special purpose-built structures. In consideration of the state of the Gerber joints, it was decided to demolish these parts of the structure (figure 6) and rebuild them along more siutable geometric lines in order to ensure an adequate seat to the support, insert the bearing devices and accomplish the continuity of the structure by consolidating the upper slabs. The new structure was realized in Rheoplastic high-strength concrete connected to the remaining parts through connecting bars (figures n. 7-8). The supports on the piers were removed, after lifting the decks alternately, and replaced by mobile unidirectional or bidirectional devices. The deck was connected at the ends to blocks built behind the abutments on special foundations with micropiles and steel tie-anchors. The connection was ensured through special shock-transmitting devices placed horizontally so as to permit slow displacements due to temperature variations and prevent impulsive actions. Two 1200 KN shock transmitters were inserted behind the abutments on each deck, capable of resisting an overall seismic force of little less than 5000 KN without damage (figure n. 9). In this way, the structure became an axially continuous beam whose longitudinal seismic forces are transferred to the blocks; the size of the foundations can resist such a force. Transversally, the continuity of the slabs allows most of the seismic forces to be transferred to the abutments - the most rigid supports - thus ensuring a more uniform distribution of the residual forces among the different piers. The forces acting on the head of the piers, up to about 1500 KN longitudinally and transversally, were reduced by the measures to tens of KN longitudinally (mainly friction forces) and to about 300 KN transversally. The measures thus led to an unloading of the piers in seismic conditions, so that no specific strengthening measures were required. In the National Roadway Board's strategy, the elimination of the surface joints will reduce the overall maintenance costs of the bridge. Special interventions on the deteriorated structures were also carried out. Three types of restoration were involved: the first involved the areas in which the surface concrete had been largely removed or which were affected by carbonation, high level of aggregates or a loss of serviceability of the corroded steel bars (thickness < 7-8 cm); the second concerned areas of damage limited to the covering concrete (thickness < 4 cm); the third essentially involved the protection of the concrete surfaces more exposed to aggressive agents and with minor cracks or deterioration.

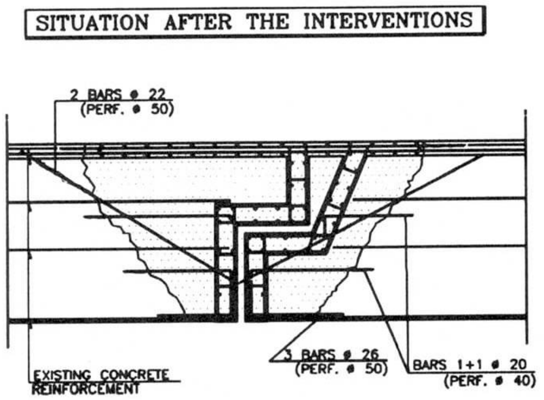


FIGURE 7

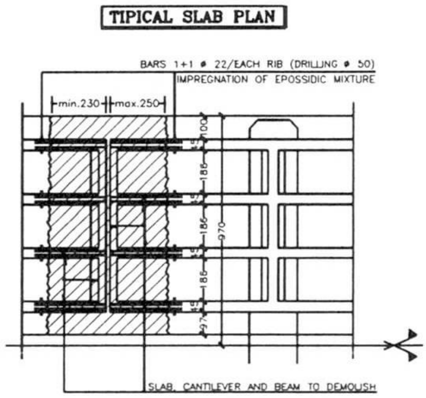


FIGURE 8

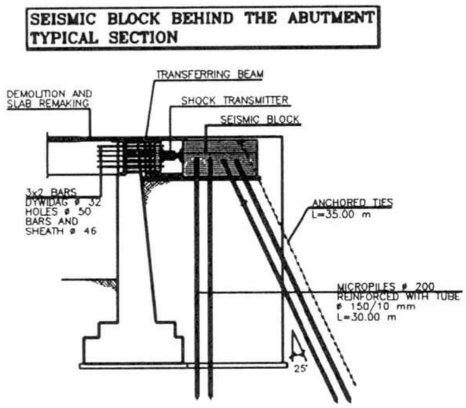


FIGURE 9

3. THE REGGIA VIADUCT

3.1 Present situation

The Reggia viaduct crosses the catch drain of the same name on the E45 Highway 30 km north of Perugia. It was built in the late seventies using the successive segment cantilever method on piers with a maximun height of 15 meters (photo 10). The cantilevers were then connected, so that the end result is a continuous 5-spans beam on 6 supports. The three central spans are 90 meters long and the lateral spans 45 meters. The supports on the central piers are of the fixed hinge type and those on

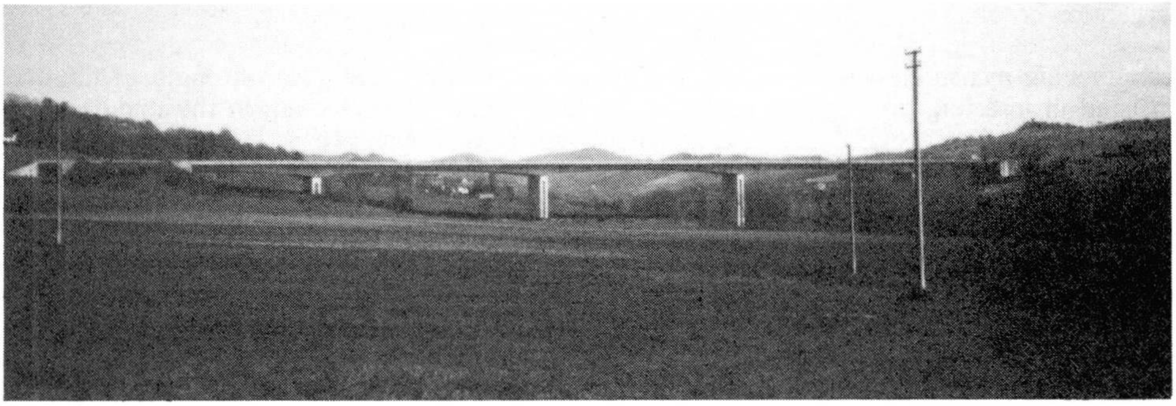


photo 10 - Reggia Viaduct - General view

the piers and on the abutments are simple supports. In order to avoid hyperstatic components during prestressing of the sewing cables of the central span, some provisional hydraulic jacks were inserted into the middle of that span. The cross section consists of a 3-cell box girders, 4.9 meters high at the level of the piers and 2.3 meters high in the midspan and on the supports of the abutments. Over the years the bridge has suffered some deflections in the lateral spans (piers 1-2 and 3-4), with a maximum amplitude of about 15 cm, while the central span shows no or minimum deflection (figure 11). These deformations called for a general re-examination of the structure, though they did not compromise the use of the viaduct.

3.2 Causes of decay and damage

The phenomena observed are related to creep processes that cannot easily be predicted at the design stage. On account of the construction method, based on a cantilevered section-by-section procedure that involved building a structure with provisional boundary conditions that differed from the final ones, the creep effects have produced a redistribution of the stress for permanent loads and, in particular, an increase in positive bending moments in the middle of the spans and a reduction near the piers (figure 12). The individual sections of the cantilevers were poured in different stages, with non-homogeneous pouring and weathering conditions, so that they presented different creep functions. Even minor uncertainties in calculating the dead or prestressing loads could also have led to considerable variations in the creep deformations, bearing in mind the effective reciprocal influences between the creep and the steel relaxation of the prestressing cables. Another factor that should be considered is the possible effect of the insertion of provisional hydraulic jacks in the middle of the central span, which may have partially compensated the creep deformations of the third span, jeopardizing the second and fourth spans.

REGGIA BRIDGE: LONGITUDINAL SECTION AND AMPLIFIED CREEP DEFORMED

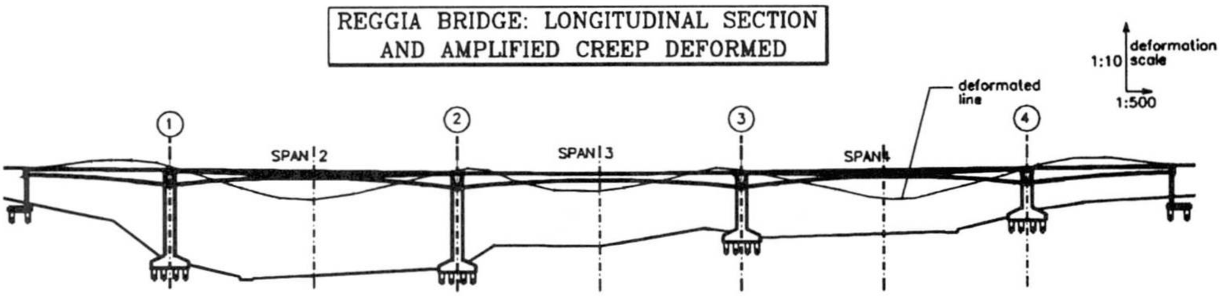


FIGURE 11

3.3 Intervention criteria

The strengthening measures were designed to enhance the bending and shear strength of the deck and consisted in inserting prestressing cables in the lower part of the section in the middle of the lateral spans and also, to a lesser extent, in the central span. Prestressing was achieved by inserting new cables within the box-girder and tensioning them prior to the casting the new levelling pavement. The new prestressing forces thus compensate either the creep effects or the loads corresponding to the new pavement. Each cable was protected by a grease sheath and anchored anchored to the diaphragms of the pierheads; they were placed along an almost rectilinear course to reduce the deviation devices. 192 six-inch wobblers were used, to provide an overall force of about 16000 KN for the lateral spans and about 10800 KN for the central one (photo 13). In order to differentiate the amount of prestressing, some cables are continuous from the first pier-head to the last, whilst others have only the length of one of the lateral spans. The only deviation device inside the box-girder, at midspan level (figure 14), consists of a steel frame connected to the ribs of the caisson to which the cable was connected after tensioning, so as to ensure continuity to the transversal section. Three devices were used for each span, one for each of the three cells of the box-girder. The frames were assembled with steel profiles and plates connected by high-strength bolts in order to allow transport and the mounting inside the box-girder. A horizontal strut with St. Andrew's crosses was provided in order to resist to the friction component of the prestressing forces. The work was successfully carried out without restriction traffic and restored about 10% of the previous deformations. The increase in safety levels was assessed at around 30%. Thus the measures adopted significantly increased the durability of the structure by closing the craks caused by creep. The load test performed on the bridge on completion of the work also showed an increase of the overall stiffness of the whole structure of about 20%.

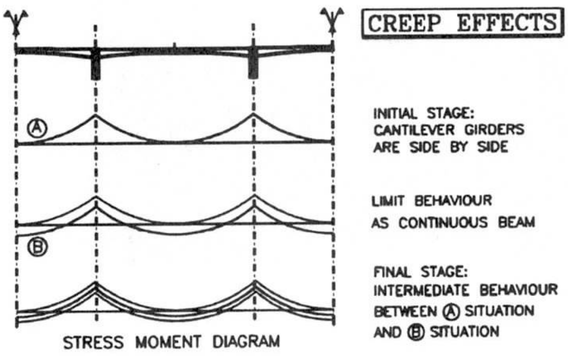


FIGURE 12

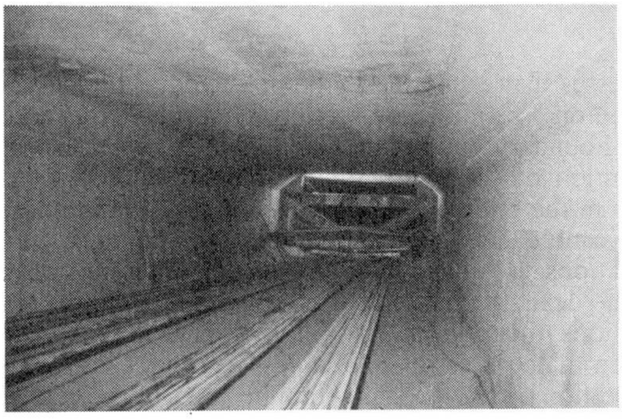


photo 13 - Prestressing cable system and deviation device frame

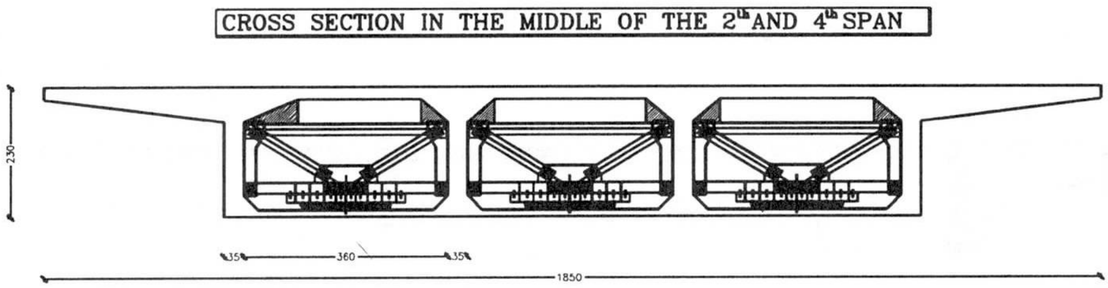


FIGURE 14