



The overall goal of the project Assessment and Rehabilitation of Central European Highway Structures (ARCHES) is to reduce any gaps in the standard of highway infrastructure between Central and Eastern European Countries (CEEC), particularly New Member States (NMS), and the rest of the EU. This key problem will be addressed by a combined approach:

- developing more appropriate tools and procedures to avoid unnecessary interventions (repairs/replacements) in structures;
- prevent the development of corrosion by simpler, and less expensive techniques, implement faster, more cost-effective, and longer lasting rehabilitation techniques (repair or strengthening) of sub-standard and unsafe bridges;
- aggressive dissemination of results and general best practice to the key stakeholders.

6th Framework Programme

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Hlavním cílem projektu ARCHES je snížit rozdíl mezi úrovní dopravní infrastruktury ve středoevropských a východoevropských zemích (CEEC), se zaměřením na nové členské země Evropské unie (NMS), a úrovní dopravní infrastruktury v ostatních členských zemích Evropské unie. Tato problematika bude řešena kombinací následujících přístupů:

- rozvoj vhodných nástrojů a postupů, které by zabraňovaly zbytečným zásahům do konstrukcí (opravy, rekonstrukce);
- předcházení rozvoje koroze pomocí jednoduchých a finančně nenáročných technologií; zavedení rychlejších, cenově výhodných a dlouhotrvajících technologií (oprav nebo zpevňování) nevyhovujících a potencionálně nebezpečných mostů;
- rozšiřování výsledků a závěrečných doporučení mezi zainteresované organizace a orgány jednotlivých zemí.



Scopo del progetto ARCHES è di ridurre il divario esistente fra il livello delle infrastrutture autostradali dell'Europa Centrale (CEEC), in particolare i Nuovi Stati Membri (NMS), ed il resto dell'Europa. Questo problema sarà affrontato con un approccio combinato:

- sviluppando nuovi strumenti e procedure per evitare interventi di riparazione manutenzione sulle strutture;
- prevenendo lo sviluppo della corrosione mediante l'impiego di tecniche semplici ed economiche;
- implementando durature e rapide tecniche di riparazione/manutenzione, economicamente vantaggiose, dei ponti che presentano bassi livelli di sicurezza;
- disseminando risultati e 'best practice' agli stakeholder chiave.



El principal objetivo de ARCHES es reducir las diferencias en el nivel de servicio existentes entre las infraestructuras viarias (puentes) de los países del Centro y Este de Europa (CEEC), en particular los nuevos Estados Miembros (NMS), y el resto de la Unión Europea.

Ello se hará en base a la siguiente metodología:

- desarrollando métodos y herramientas avanzadas de evaluación y monitorización estructural para evitar intervenciones (reparaciones/ sustituciones) innecesarias;
- evitando la corrosión de armaduras mediante técnicas más simples, baratas, fáciles de aplicar y más efectivas, así como técnicas de reparación más durables;
- diseminando intensamente los resultados del proyecto y las guías de buena práctica entre las Administraciones responsables.



L'objectif du projet ARCHES est de réduire l'écart au niveau des infrastructures routières entre les pays d'Europe centrale et de l'est (CEEC), particulièrement les nouveaux états membres (NMS), et le reste de l'Union Européenne. Ce problème clé sera traité au

moyen d'une approche combinée:

- développer des outils et des procédures plus appropriés afin d'éviter des interventions inutiles (remises en état/remplacements) sur les structures;
- prévenir le développement de la corrosion par des techniques plus simples et moins coûteuses, mettre en œuvre des techniques de réhabilitation (remise en état ou renforcement) plus rentables et plus durables, pour les ponts non conformes aux normes actuelles et dont la sécurité est insuffisante;
- dissémination proactive des résultats et des règles de l'art aux intervenants clés.



ARCHESi üldine eesmärk on vähendada maanteeinfrastruktuuri standardite erinevusi Kesk- ja Ida-Euroopa riikide, eriti uute liikmesriikide, ning ülejäänud Euroopa Liidu riikide vahel. Antud probleemile lähenetakse kombineeritult:

- luuakse sobivamaid vahendeid ja võtteid, et vältida asjatuid sekkumisi (parandustööd või välja vahetamine) rajatistesse;
- takistatakse korrosiooni teket lihtsamate ja odavamate meetodite abil, juurutatakse standardile mittevastavate ja ohtlike sildade remondiks kiiremaid, tulusamaid ja kauem kestvaid taastusmeetodeid (parandustööd või tugevdamine);
- levitatakse agressiivselt tulemusi ja üldisi häid tavasid puuduvat teavet peamistele huvirühmadele.



Het doel van ARCHES is de kloof te verkleinen in het niveau van snelweginfrastructuur tussen Centraal- en Oosteuropese landen (CEEC), en in het bijzonder de Nieuwe Lidstaten (NMS), en de rest van de EU. Dit sleutelprobleem zal worden benaderd met een gecombineerde aanpak:

- ontwikkelen van geschiktere gereedschappen en procedures om onnodige interventies (reparatie/vervanging) aan constructies te voorkomen;
- de ontwikkeling van corrosie te voorkomen door eenvoudiger en goedkopere technieken en snellere, meer kosteneffectieve en duurzamere herstelmethoden (reparatie of versterken) in te voeren voor onvoldoende functionerende en onveilige bruggen;
- agressieve disseminatie van resultaten en best practice naar de belangrijkste stakeholders.



Opći cilj projekta ARCHES je povećati standard prometne infrastrukture zemalja Istočne Europe, posebice novih članica Europske Unije, odnosno smanjiti razlike u nivou kvalitete i sigurnosti na prometnicama Istočne i Centralne Europe. Taj ključni

problem će se sagledavati s više stajališta:

- razvojem prihvatljivijih metoda i procedura za ocjenu stanja postojećih konstrukcija, kako bi se izbjegli nepotrebni popravci i zamjene postojećih konstrukcija;
- sprečavanjem razvoja korozije i dotrajavanja konstrukcija primjenom novih - bržih, ekonomičnijih i trajnijih, metoda za zaštitu i popravak dotrajalih i nesigurnih konstrukcija/mostova u postojećoj infrastrukturi;
- snažno širenje rezultata projekta i iskustva do vodećih interesnih grupa.



Das Hauptziel von ARCHES ist es, die Straßeninfrastruktur der Zentral- und Osteuropäischen Länder, insbesondere der Neuen EU-Mitgliedsstaaten, an den vorhandenen Standard der restlichen EU-Länder anzupassen. Dieser Problematik wird durch einen kombinierten Ansatz entgegengewirkt:

- Entwicklung von passenden Werkzeugen und Verfahren, um Eingriffe (Instandsetzungs- oder Erhaltungsmaßnahmen) in die Infrastruktur gezielt steuern zu können;
- Minimierung von Korrosion durch einfachere und kosteneffizientere Maßnahmen; Implementierung schnellerer, kosteneffizienterer und langfristiger Instandhaltungs- bzw. Instandsetzungs-Maßnahmen für Substandard- bzw. für beschädigte Brücken;
- Proaktive Verteilung der Ergebnisse und Vermarktung von Best Practices an wichtige Stakeholder.



Glavni cilj projekta ARCHES je zmanjšati razkorak v stanju cestne infrastrukture med srednje in vzhodnoevropskimi državami, še posebno novimi članicami Evropske unije na eni, ter razvitimi evropskimi državami na drugi strani. V ta namen bo projekt s

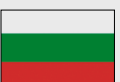
kombiniranim pristopom:

- izpopolnjeval orodja in postopke za preprečevanje nepotrebnih posegov (obnov/zamenjav) na objektih;
- razvijal metode za preprečevanje razvoja korozije z enostavnejšimi, cenejšimi, učinkovitejšimi in dolgotrajnejšimi postopki rehabilitacije (obnov/ojačitve) poškodovanih objektov;
- širil in objavjal rezultate in izkušnje med lastniki in upravljavci infrastrukture



Podstawowym celem Projektu Ocena stanu i metody napraw drogowych obiektów inżynierskich w Europie Centralnej (ARCHES) jest zniwelowanie różnicy w standardach technicznych drogowych obiektów inżynierskich pomiędzy krajami 'starej' Unii Europejskiej, a krajami Europy Środkowej i Centralnej, ze szczególnym uwzględnieniem Nowych Krajów Członkowskich UE. Podstawowymi działaniami w ramach ARCHES będą:

- opracowanie odpowiednich instrumentów i procedur oceny stanu obiektów pozwalających na lepsze zarządzanie środkami przeznaczonymi na utrzymanie obiektów drogowych;
- opracowanie prostszych i tańszych technologii zabezpieczenia antykorozyjnego obiektów oraz wprowadzenie szybkich, tanich i trwałych technologii napraw i wzmacniania zniszczonych lub niepewnych mostów;
- szerokie rozpowszechnianie wyników prac i doświadczeń wśród wszystkich zainteresowanych.



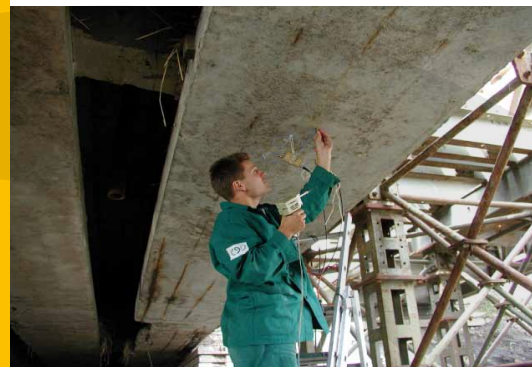
Крайната цел на проекта ARCHES е да се намали разликата в стандарта за пътната инфраструктура между страните от Централна и Източна Европа (CEEC), особено новите страни-членки, и останалите Европейски страни. Този основен проблем ще бъде разглеждан с помощта на комбиниран подход:

- разработване на по-подходящи инструменти и процедури за избягване на ненужните намеси (ремонти/ подмени) в конструкциите;
- предотвратяване развитието на корозия чрез по-прости и по-евтини технологии; внедряване на по-бързи, по-ефективни по отношение на разходи и по-дълготрайни технологии за рехабилитация (ремонт или усиление) на мостове, които не отговарят на стандартите и са опасни;
- разпространяване и налагане на резултатите и основните най-добри практики до заинтересованите страни.

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INTRODUCTION

The Sixth Framework Program ARCHES, (“Assessment and Rehabilitation of Central European Highway Structures”) was realised within the Sustainable Surface Transport area. Since September 2006, 12 partners from all around Europe (including the Central and Eastern European Countries of the EU15 (CEEC) and the New Member States of the EU10) worked together on the project which was coordinated by an Eastern European partner: the Road and Bridge Research Institute from Poland. It must be mentioned that most of the Partners were appointed through the Forum of European National Highway Research Laboratories (FEHRL), which also was the initiative body of the Project proposal 4 years ago. More than two years were dedicated to literature studying, basic experiments and comprehensive laboratory and theoretical investigations. This last, and final year of the project was devoted to practical experiments put into the real life of highway structures.

One has to remember that the strategic objective of the project was to reduce, in a sustainable way, the gap in the standard of highway structures between the CEEC and the rest of the EU. The idea was to achieve this by developing appropriate tools and procedures for a more efficient assessment, and faster, cost-effective, and long lasting rehabilitations (by reparations or strengthening) of sub-standard highway structures.

To achieve its scientific and technological goals, ARCHES focused on structural assessment and monitoring, strategies to prevent deterioration and optimum rehabilitation of highway structures by complementary techniques. The project is organised in 4 technical work packages, with the following conceptual approach:

- Optimise the use of existing infrastructure through better safety assessment and monitoring procedures which will avoid interventions, i.e., avoid unnecessarily replacing or rehabilitating structures that are in fact perfectly safe (WP2);
- Monitor and prevent corrosion of existing reinforcement and develop innovative new reinforcement materials that are highly resistant to corrosion (WP3);
- Strengthen the infrastructure of bridges by means of bonded reinforcements (WP4);
- Harden highway structures with Ultra High Performance Fibre Reinforced Concretes (UHPC) applied in severely exposed zones to dramatically increase their durability (WP5).

More specifically, Work packages 2, 3, and 5 are at the origin of two major achievements of the Project:

- The proof load testing (a rather rare experiment in a full scale version) of the Barcza Bridge in southern Poland was realised in November 2008. That experiment has a vital impact on the WP2 Deliverable, which will attract bridge owners for more detailed and more accurate bridge structure assessment.
- Within WP3, three achievements need special attention: the recommendation for the use of the low alloyed reinforcement available on the market and the marine environment test site, local cathodic protection tests including the numerical model code and the development of electrical resistant probes for corrosion monitoring made of both, and the black steel and low alloyed steel.
- For WP5, the newly developed UHPC with Slovenian materials and improved rheological properties was successfully applied in July 2009 for the rehabilitation of the Log Čezsoški bridge (Slovenia) with slopes of 5%, opening the way to a wider dissemination of this concept, in most challenging conditions of application



WP2 DEVELOPING APPROPRIATE TECHNIQUES FOR OPTIMAL BRIDGE ASSESSMENT

By Joan Ramon Casas, WP2 leader

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The optimal assessment is critical in reducing the number of existing bridges in CEE countries that should need retrofitting in the near future, to the minimum. Optimal assessment requires an accurate knowledge of actual loads and resistance. Regarding the loading part, traffic data has been gathered within WP2 and is available from WIM records carried out in The Netherlands, Poland, Slovenia, Slovakia and the Czech Republic. This traffic data has been analyzed and used to obtain, via simulation, the characteristic values of the traffic action for these countries (4 New Member States (NMS) + Holland for comparison). The results show that the traffic action is significantly lower for all NMS when compared to Western-European countries. Also, in all cases, it is advised that the presence of unescorted exceptional vehicles (as those presented in the figures 2.1 and 2.2) into the traffic flow, may produce characteristic traffic effects in bridges higher than those caused by Load Model 1 in the Eurocode for highway traffic actions in bridges. This preliminary result needs, of course, further investigation due to its significance in the assessment of bridge capacity in NMS and CEEC.



Figure 2.1 Axle crane with a total weight of 1110 kN



Figure 2.2 Low-loader vehicle with a total weight of 1450 kN

In order to explore more accurate methods for bridge response assessment, the so-called proof load testing is investigated within WP2. A proof load test was carried out on a real bridge close to the city of Barcza in Poland (fig. 2.3). The bridge is composed of precast pre-stressed concrete girders and had to be replaced in the near future. The bridge was loaded with concrete and steel weights (fig. 2.4) up to a load higher than the cracking load of the most loaded beam. At the same time, acoustic emission sensors and other monitoring equipment was used to follow the loading process. The results of the acoustic emission (fig. 2.5) predicted very precisely the time when the first crack in the beam would appear. Therefore, this monitoring technique has shown as a very useful and promising tool in the control of the load level where the test should stop when a proof load is carried out in a bridge in order to not produce any damage.

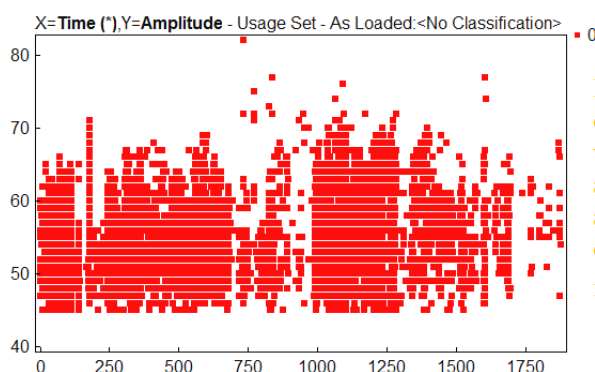


Figure 2.5 Load step No. 8: five concrete slab layers + three steel weights layers in the deck. Maximum acoustic emission activity is detected at girder mid-span. However, no cracking is still detectable by visual inspection.



Figure 2.3 General view of the Barcza bridge



Figure 2.4 Proof load testing execution on the bridge

WP3 CORROSION MONITORING, PREVENTION AND PROTECTION

By Aljosa Sajna, WP3 leader

The objective of WP3 was to provide and test techniques and materials that will arrest corrosion in existing concrete structures.

The corrosion of reinforcing steel is the main reason for the reduced service life of concrete structures, especially for those exposed to aggressive environments. As a result, the repair costs of bridges, tunnels, coastal structures, etc. constitute a major part of the current spending on infrastructure. The enormous costs and safety issues associated with corrosion of rebars and prestressing cables in concrete have resulted in the development of a wide range of new technologies and materials to increase the durability of concrete structures and their repairs. However, most of the available methods for repair of corrosion related damage have shortcomings: they are expensive, disrupt traffic and, in some cases, their effectiveness is short lived. Increasing interest exists in the development of intervention methods that meet social and environmental as well as technical and economic needs, but research on such methods is still in its infancy.

WP3.1 LOW-ALLOYED STEEL REINFORCEMENT

The Arches project's WP3.1 dedicated itself to researching the effects of using low-alloyed reinforcement. The objective was to:

- Determine an **optimal use** of low-alloy steel reinforcement
- To **define the limit conditions** where their use might still be efficient
- **Compare** low alloyed reinforcements available on the market and
- **Prepare basic cost analysis** of the use of different low alloyed steel reinforcement types

A testing program was set up to test corrosion resistance in simulated pore water with different pH values and Cl⁻ concentrations (polarization resistance, potentiodynamic measurements, electro-chemical impedance spectroscopy) and in concrete specimens (chosen low-alloy steels embedded in them, corrosion induced by wetting and drying with chloride solution, specimens tested with electrochemical measurements). ER (electrochemical resistance) probes were embedded in concrete specimens for corrosion monitoring. Besides state of the art research and laboratory testing, the WP3.1 partners established an exposure site in the real marine environment. the WP3.1 partners established an exposure site in the real marine environment.



WP 3.2 CATHODIC PROTECTION (CP) SYSTEMS

The objective of WP3.2 was to design and test innovative, smart – which means economical and effective – CP systems for bridges; to design small and cheap CP systems based on light weight solutions, either based on carbon (conductive coating, carbon fibre textile anodes) or titanium strips. A numerical tool was developed for calculating current and potential distribution. Basic designs of smart CP systems were numerically verified and tailor-made for specific problem areas in typical bridges of NMS and CEEC. Two pilot smart CP systems were applied to bridges in Slovenia and Poland.



In Slovenia, from March 2008 until August 2008, the evaluation of the corroded bridge, the repair works and the application of the CP system were performed. Three different CP test systems were applied to three cantilever parts of two cross beams supporting a bridge deck by LEGGEDOOR, the “standard” anode, the “smart strip” anode and the “minimal” anode, leaving one cantilever part unprotected as a reference field. After switch-on of all three CP test systems, measurements were performed. Based on the measurement results the current were optimised and the numerical model used for the CP system simulation was adopted.

Early data were used to validate a model for short term effects of current during the start up phase of CP systems. Their effectiveness of the CP systems is being tested with advanced corrosion monitoring sensors (ER probes) and by conventional reference electrode (depolarisation).

In Poland, the work started the first week of December 2008 with mortar supplied by LEGGEDOOR, who also provided training in IBDiM on how to install anodes.



WITHIN WP3.3 (CORROSION MONITORING), small electrical resistance (ER) probes were developed. Furthermore, ER probes were installed in concrete samples and test sites of the WP3.1 and WP3.2 to support those tests and to be compared with other corrosion monitoring methods (weight loss, galvanostatic pulse).

Beside the black steel ER probes, stainless steel ER probes were successfully developed. Low carbon steel ER probes were introduced to reinforced concrete specimens and under the cathodic protection (CP), low-alloyed steel ER probes were installed in concrete specimens (slabs and columns) with low-alloyed steel reinforcement.



WP4 STRENGTHENING WITH FRP GLUED STRIPS

By Marek Lagoda, WP4 leader

The WP 4 Strengthening with FRP glued strips works on bridge strengthening by externally bonding reinforcement to adapt bridge structures for real loadings origin from heavier traffic. Its objective is to elaborate guidelines and procedures for structure elements strengthening with prestressed FRP elements and structure supports (columns) strengthening.

The necessity of bridge strengthening was caused by the change of load conditions, which appeared in the last twenty years as well as the material deterioration. Steel plates and composite materials give a great opportunity of bridge strengthening. There is a current question on durability and future behaviour of this particular way of strengthening, apart from hasty results of implementing this method. The other problem apart from superstructure strengthening is durability of the supports. The technology of concrete columns wrapping with FRP materials seems to be promising.

One important application of FRP composites is a wrap or jackets for the confinement of reinforced concrete (RC) columns for enhanced strength and ductility. In FRP-confined concrete subject to axial compression, the FRP is principally loaded in hoop tension while the concrete is loaded in tri-axial compression, so that both materials are used to their best advantages. Both the strength and the ultimate strain of concrete can be greatly enhanced as a result of FRP confinement, while the high tensile strength of FRP can be fully utilized. Instead of the brittle behaviour exhibited by both materials, FRP-confined concrete possesses greatly enhanced ductility.



WP5 ULTRA HIGH PERFORMANCE FIBRE REINFORCED CONCRETE (UHPFRC) FOR REHABILITATION OF BRIDGES – RECENT ADVANCES IN SLOVENIA

By Emmanuel Denarié, WP5 leader

The increasing volume of European transport urgently requires an effective road and rail system in Central European and Eastern Countries (CEEC) with a major investment in building new and assessing and rehabilitating old structures. Ultra-High Performance Fibre Reinforced Concretes (UHPFRC), characterized by a very low water/binder ratio, high binder content and an optimized fibrous reinforcement, provide the structural engineer with a unique combination of extremely low permeability, high strength and tensile strain hardening. UHPFRC are perfectly suited to the rehabilitation of reinforced concrete structures in critical zones subjected to an aggressive environment and to significant mechanical stresses, to provide a long-term durability and thus avoid multiple interventions on structures during their service life.

Extensive R&D works performed during EU project SAMARIS and various full scale applications in Switzerland on bridges have demonstrated that UHPFRC technology is mature for cast in-situ applications of rehabilitation, using standard equipments. The construction costs of the proposed technique are not significantly higher than more traditional solutions, and the duration of the construction works and closing of traffic lanes can be largely reduced, to the greatest satisfaction of the bridge owners.

EU Project ARCHES dedicates a significant effort to demonstrate the applicability of this innovative rehabilitation technique in CEEC, with cheaper UHPFRC based on locally available components and improved rheological properties (tolerance to slope of the substrate at fresh state) and processing techniques.

Achievement of tensile strain hardening, extremely low permeability and self-compacting character is indeed a challenge that few current UHPFRC recipes can satisfy. An original concept of Ultra High Performance matrix with a high dosage of mineral addition has been developed that makes the application of UHPFRC technology feasible with a wide range of locally available cements and superplasticisers. This concept was validated with both Slovenian and Polish products. In a further step, the rheology of those mixes has been adapted to enable them to accommodate 5 % slopes of the substrates at fresh state.



This new material was successfully applied in July 2009, for the rehabilitation of the deck and footpaths of the Log Čezsoški bridge (Slovenia) with challenging slopes of 5%, opening the way to a wider dissemination of this concept, in most demanding conditions of application.

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OR FURTHER INFORMATION

After 3 years of hard work we have reached the end of the ARCHES Project "Assessment and Rehabilitation of Central European Highway Structures". The seventeen research institutes and technical Universities who took part in this project have been able to produce several outcomes which will be discussed in detail at the ARCHES and SPENS Final Seminar. The presentations given here reflect only a fraction of the work performed during the Project.

For further information, a more in depth view can be found on the official project web site, <http://arches.fehrl.org>. Throughout the project, all of the deliverables and reports have been uploaded. This website will continuously be updated, even after the project has ended. Therefore, if you are interested in following the progress after the Final Seminar, all future articles and papers presented at different international and national conferences, prepared on the basis of the work done within the Project, will also be uploaded.

Finally, within the next few months, you will be able to find the national versions of the summary reports of all Deliverables prepared in cooperation with the CERTAIN Project on the website as well.



[HTTP://ARCHES.FEHLR.ORG](http://arches.fehrl.org)



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