Shape Memory Alloy retrofitting of columns for future resilient infrastructures

EP/N029127/1

The aim of this research is to investigate the application of the shape memory alloy NiTiNb to retrofit reinforced concrete bridge columns. The novelty of this work lies in addressing columns subjected to a sudden impact by a heavy goods vehicle.

Road vehicle impacts are the second cause of bridge failures in the US and much more frequent than failures due to earthquakes. This study intends to model the mechanical response of bridge columns retrofitted with NiTiNb spirals and quantify their resilience in resisting lateral impact loads. The method exploits the shape memory effect, i.e. the capacity of some metallic alloys of recovering plastic deformations through a thermo-elastic transformation.

The retrofitting technique simply consists in winding a prestrained shape memory alloy wire around a column, constraining the two ends by means of mechanical fasteners and heating the spiral above a characteristic temperature using electrical current or a gas torch.

The SMA NiTiNb, a Nickel, Titanium and Niobium alloy, can recover above 8% strain and has a range of characteristic temperatures that make it suitable for applications in structural engineering, and in particular the one promoted here, i.e. enhancing the capacity of bridge support elements to resist impacts from road vehicles by applying active confinement to the member core.

Nitinol based Shape Memory Alloys (SMA) also exhibit high strength, high energy absorption capacity, high damping, good fatigue resistance, good corrosion resistance and excellent re-centring ability.

At present passive damage mitigation techniques, such as concrete or steel jacketing and fibre reinforced polymer fabrics, are most commonly used to retrofit structural elements. Active confinement, however, which is the focus of this work, is much more effective in reducing damage since it acts at an earlier stage in the event, before any lateral loads are applied.

The project is structured in three main tasks: the thermo-mechanical characterization of NiTiNb alloy; the development of a set of comparative numerical analyses, using a full scale LS-DYNA finite element model of RC columns hit by heavy goods vehicles before and after being retrofitted with NiTiNb spirals; and a small scale drop test used for validation purposes to give credibility to the FE model predictions.

The outcomes of this research will be immediately applicable to circular RC concrete columns supporting bridge decks, but also to a wide range of structures such as underground car parks, railway bridges and buildings located close to major roads or vulnerable to malicious vehicle impact. The project will contribute toward building resilience in critical national infrastructures and can be used to prevent vulnerability of strategic buildings.

Since the method relies on the concept of active confinement of concrete it would not only prevent the vulnerability of undamaged structural members but also restore the functionality of severely damaged columns. Moreover the technique is suitable also for emergency repair since it does not need mechanical pre-stressing of the wire and can be implemented with significant reduction of labour and time with respect to other retrofitting methods.