Lipid droplets: a new player in colorectal cancer stem cells unveiled by spectroscopic imaging

Bridge Maintenance, Safety, Management, Life-Cycle Sustainability and Innovations – Yokota & Frangopol (eds)

BRIDGE|50 research project: Residual structural performance of a 50-year-old bridge

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ABSTRACT: This paper deals with the BRIDGE|50 research project aimed at investigating the residual structural performance of a 50-year-old concrete bridge recently dismantled in Italy. A group of 29 precast prestressed beams, including 25 I-beams and four box beams, and two pier caps has been placed in a testing site. The preliminary activities already developed and the planned experimental program are discussed. The project includes photographic mappings, drone surveys, non-destructive testing, full-scale load tests, and extraction of a large number of samples from the tested structural elements for laboratory tests.

1 INTRODUCTION

Many studies and news in recent years raised alarms about the detrimental impact of aging, fatigue, and deterioration processes on civil structures and infrastructure systems, particularly bridges and transportation infrastructure networks, and warned about the substantial underinvestment in infrastructure repair and maintenance in most developed countries. This is becoming a major problem, particularly in Italy, because huge stocks of bridges and infrastructure facilities built over the past 50 years are rapidly approaching the end of the service life. The scale of repair or replacement needs is particularly large and represents a key obstacle to sustainable development of countries. According to the American Society of Civil Engineers (ASCE), in United States "the most recent estimate puts the nation's backlog of bridge rehabilitation needs at $123 billion" (ASCE 2017).

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To face with this need, civil engineering is undergoing a profound change towards a life-cycle oriented design philosophy. ASCE is also promoting the use of life-cycle cost analysis in conjunction with the Grand Challenge of reducing life-cycle costs of civil infrastructure projects by 50% by 2025. In this context, significant advances have been accomplished for modeling, analysis, design, maintenance and rehabilitation of deteriorating structures and infrastructures. These advances are perceived to be at the heart of a modern approach to bridge and structural engineering and will be of crucial importance to consolidate and enhance criteria, methods and procedures to protect, maintain and improve the safety, durability, robustness, functionality, and disaster resilience of critical infrastructures (Biondini & Frangopol 2016, 2019).

The impact of aging and deterioration processes can be particularly high for reinforced concrete (RC) and prestressed concrete (PC) structures. In the early 20th century engineers have been under the impression that concrete structures would last for a very long time. The Pantheon in Rome was built almost 2000 years ago and many others notable old concrete structures are still in service. However, the combined use of concrete with reinforcing and prestressing steel and the exposure to aggressive environments led over time to serious deterioration problems, such as steel corrosion, for most of the structures – especially bridges – built in the 50s, 60s, and 70s. The use of modern concrete materials and advanced techniques for damage protection may partially solve durability problems. However, inspection procedures, monitoring activities, and maintenance interventions are necessary to ensure adequate long-term structural performance. Furthermore, increasing the lifespan of materials, concrete and steel, cannot guarantee a lifetime extension of the structure itself, which may depend on several other important factors such as structural detailing at the component level and conceptual design of the overall structural system.

A recent survey (Biondini & Frangopol 2018) indicated that structural design codes, standards and specifications incorporating life-cycle concepts and addressing life-cycle methods and procedures are of primary importance for the successful implementation in practice of a modern and rational life-cycle-oriented design approach. Moreover, advanced life-cycle models are well established for some of the most detrimental damage processes, such as corrosion and fatigue, and are rapidly becoming available for a wider spectrum of deterioration mechanisms (Ellingwood 2005). However, deterioration models are very sensitive to change of the probabilistic parameters of the input random variables, and their robust validation and accurate calibration are difficult tasks to be performed because of the limited availability of data. Further efforts in this direction, aimed at gathering new data from both inspection of existing structures and experimental tests, are crucial for a successful implementation in practice of life-cycle methods. The BRIDGE|50 research project has been recently established to this purpose. The project will investigate the residual structural performance of a decommissioned 50-year-old road bridge based on a campaign of experimental tests. The results of BRIDGE|50 are expected to contribute a modern approach to life-cycle design of bridges and to improve safety, maintenance, and management of existing infrastructure systems.

2 RESEARCH PROJECT AND MANAGEMENT COMMITTEE

BRIDGE|50 is a research project recently launched in Italy in the context of the Torino-Ceres construction works for realization of a new infrastructure system, urban redevelopment, and sub-services renewal in the northern area of Turin. The research project includes a wide experimental campaign with full-scale load tests on the structural members of a 80-span concrete viaduct dismantled after a lifetime of about 50 years. To this purpose, a group of PC deck beams and pier caps has been moved and stored in a testing site.

The project proposal started in 2017 under the initiative of Lombardi Engineering and Politecnico di Milano and was finally established in 2018 jointly with Politecnico di Torino based on a research agreement also involving several public authorities and private companies. A Management Committee, including one representative from each of the following research partners, has been formed to run the project:

- S.C.R. Piemonte (President)
- Politecnico di Milano (Scientific Coordinator)
- Lombardi Engineering (Secretary)
- Politecnico di Torino
- Piedmont Region
- City of Turin
- Metropolitan City of Turin
- TNE Torino Nuova Economia
- ATI Itinera & C.M.B.
- ATI Despe & Perino Piero
- Quaranta Group

The research activity is carried out jointly and in close cooperation by Politecnico di Milano and Politecnico di Torino. The testing site is located in Turin in a restricted area owned by TNE and managed under the supervision of Politecnico di Torino.

3 CORSO GROSSETO VIADUCT AND BRIDGE DECONSTRUCTION

The 50-year-old Corso Grosseto viaduct is a 80-span double deck road viaduct recently dismantled in Turin, Italy. Figure 1 show an aerial view of the viaduct still

Figure 1. Aerial view of the Corso Grosseto viaduct.

in service. The main bridge spans range from 16 to 24 m, for a total length of the viaduct of about 1.4 km. The bridge deck is formed by a system of precast PC beams, including ten inner I-beams and two lateral box beams, with top cast-in-situ RC slab, as shown in Figure 2. The deck girders are simply supported over each span by RC piers with tapered PC pier caps. The bridge, at the end of its service life, exhibits severe deterioration mainly due to corrosion localized on both lateral box beams and pier caps (Figure 3). Additional historical and technical information about the viaduct is available in Savino et al. (2020).

The viaduct has been demolished in 2019. Two adjacent spans of the viaduct have been preserved and

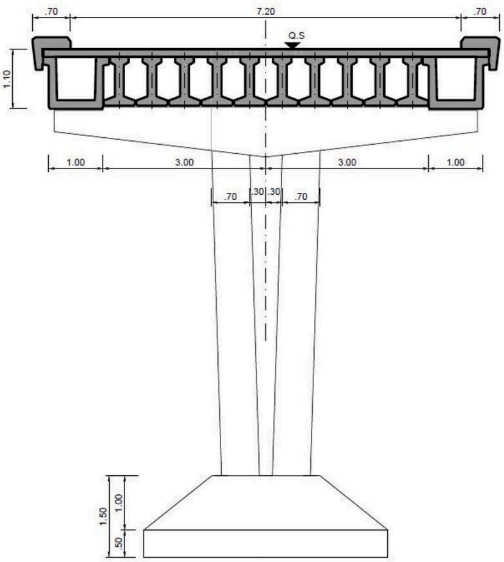


Figure 2. Bridge deck cross-section.

Figure 3. View of the bridge deck and details of the pier caps.

deconstructed according to the plan shown in Figure 4 by cutting the structural members, including 29 PC deck beams (25 I-beams and four box beams) and

Figure 4. Deck beams and pier caps selected for testing.

two PC pier caps, by using rotating disks with diamond wires (Figure 5). Therefore, the structural members have been lifted (Figure 6) and moved by trucks to the testing site (Figure 7). Figure 8 shows some of the beams during the storing process, with the beams placed sequentially on New Jersey supporting members. A detailed description of the dismantling and deconstruction process of the bridge and setup of the testing site is described in Anghileri et al. (2020).

Figure 5. Cutting the beams of the bridge deck.

Figure 6. Lifting of a pier cap.

Figure 7. Beams moved by trucks to the testing site.

Figure 8. Beams placed sequentially on New Jersey supporting members in the testing site.

4 PRELIMINARY INVESTIGATIONS

The first stage of the research project involved a series of preliminary activities conducted onsite before the dismantling of the viaduct. These activities include visual inspections of the bridge structure, concrete coring from a bridge pier and carbonation tests, and dynamic identification experimental tests on selected adjacent spans of the viaduct including the structural elements to be tested.

Visual inspections have been conducted according to national and international standards with the participation of several local and national public authorities and private managing bodies (Beltrami et al. 2020). The participants have been organized in inspection teams and each group filled one or more bridge inspection forms according to different standards established in Italy and other countries, including United States and Canada (Figure 9).

The large and diversified amount of data gathered through this activity will be elaborated according to inspection models typically used in practice. These results will be compared with the outcome of the experimental tests to validate, both in qualitative and quantitative terms, the effectiveness, representativeness, and accuracy of existing bridge inspection procedures.

Concrete split cores have been extracted from a bridge pier and carbonation depth is assessed using a phenolphthalein solution as an indication of the location of the depassivation front, with possible corrosion in the zone ahead of this front (Figure 10). These results will complement the information from experimental load tests on both deck beams and pier caps.

Finally, a preliminary dynamic tests campaign has been carried out on bridge decks. The purpose of this campaign is to characterize the dynamic behavior of the decks under service condition. Dynamic measurements have been acquired by using different excitation sources (Figure 11). The collected data have been analyzed in order to extract the principal

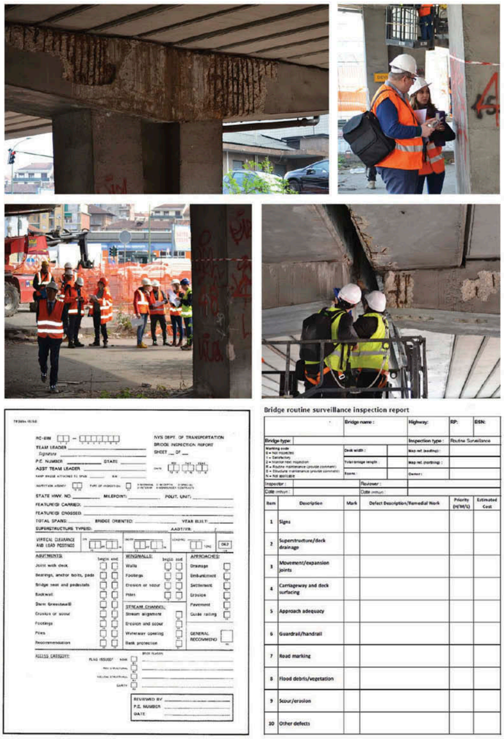


Figure 9. Bridge inspection procedures and standard forms.

Figure 10. Concrete split coring and carbonation tests.

modal components and the outcomes have been compared with the analytical results obtained by finite element analysis. A detailed description of this activity and a critical appraisal of the results are reported in Quattrone et al. (2020). The comparison of these results with those provided by full scale experimental tests to be conducted in the testing site

Figure 11. Dynamic identification experimental tests.

will be used to better investigate the effectiveness of the dynamic identification procedures in the assessment of aging bridges, explore the effects of structural deterioration on both the behavior of single beams and global response of the investigated bridge typology.

5 EXPERIMENTAL PROGRAM

Contextually to the dismantling of the viaduct, 29 deck beams (25 I-beams and four box beams) and two pier caps have been collected from the deconstruction of two adjacent bridge spans and moved to the testing site. Figure 12 shows a series of deck beams (Figure 12a,b,c) and one pier cap (Figure 12d). The planned on-site activities include photographic mapping of the structural elements, drone surveys, non-destructive diagnostic tests, full-scale load tests, and a large number of samples from the tested structural elements (concrete cores and samples of reinforcing steel bars and prestressing steel wires) for laboratory mechanical and chemical-physical tests to be performed at Politecnico di Milano and Politecnico di Torino.

Preliminary photographic mappings and drone surveys have been performed. Figure 13 shows the sequence of a mapping of photographic images to 3D surfaces. This mapping is used to detect damage and cracking states, as shown in Figure 14 for a deck beam. Extensive non-destructive diagnostic tests, including sclerometric, magnetometric, and ultrasonic investigations have been also performed (Figure 15).

The results of the mappings, surveys and diagnostics will be used to better plan the full scale load tests and complement the information from the test results. The load tests on the 29 deck beams will be performed using a four-point bending steel framework. Figure 16 shows a preliminary scheme of the framework designed for large scale testing and provided by the Interdepartmental center SISCON (Safety of Infrastructure and Construction of Politecnico di Torino).

Multiple load tests are planned, including tests under service loadings (elastic behavior), in the post-

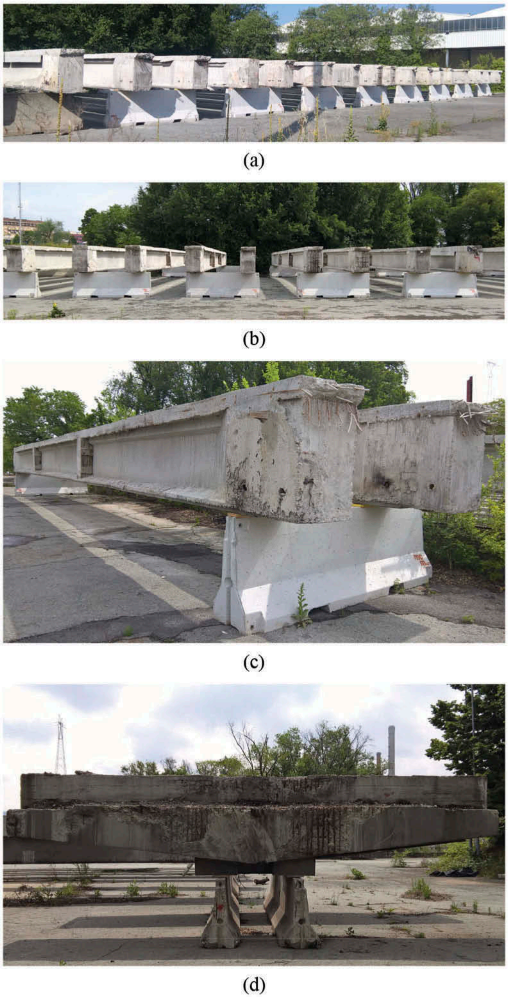
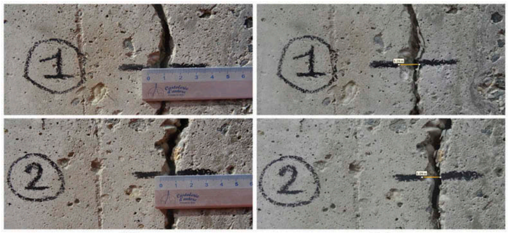


Figure 12. View of the structural elements stored in the testing site (29 deck beams, including 25 I-beams and four box beams, and two pier caps): (a,b,c) deck beams; (d) pier cap.

Figure 13. Mapping of photographic images to 3D surfaces.



(a) (b)

Figure 14. Photographic mapping for damage and cracking detection: (a) photographic images and (b) mappings.

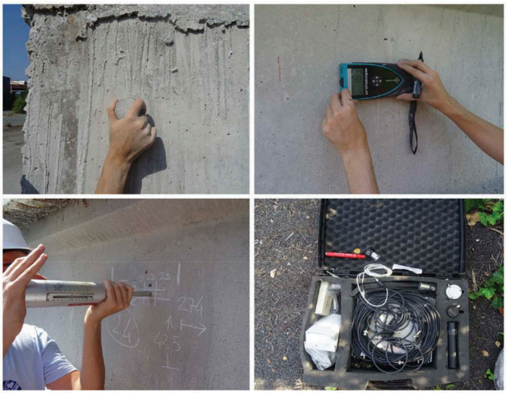


Figure 15. Some steps of the sclerometric, magnetometric, and ultrasonic investigations on deck beams.

elastic phase (damaged members), and up to collapse. Different types of bending and shear failures will be investigated based by varying the points of application of the loading system (Figure 16). Some selected beams tested in the post-elastic phase will be repaired using different repair techniques and tested again up to collapse. Moreover, load tests will be carried out on selected beams after artificial damage is applied to investigate their susceptibility

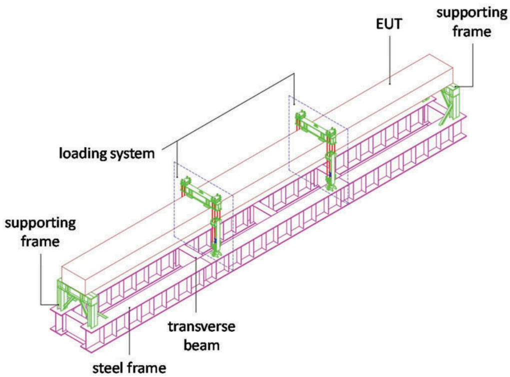


Figure 16. Preliminary scheme of the four-point bending steel framework for testing the PC deck beams.

to disproportioned collapse, i.e. structural robustness. Finally, load tests on the pier caps will be performed, with emphasis on the shear behavior of the corbels affected by severe corrosion. Different measurement techniques and devices, including fiber-optic sensors, will be used for data acquisition and storage during the load tests.

The objective of this experimental program is gathering new data concerning the residual structural performance of existing concrete structures and contribute, in this way, to support a modern approach to life-cycle design, assessment, inspection, monitoring, repair, strengthening, maintenance, and management of bridges and infrastructure systems. The participation and interest of several partners from universities, public authorities, and private companies represents a key factor to achieve this ambitious goal (Figure 17).

6 CONCLUSIONS

This paper presented the experimental program and reported about the preliminary investigations of the BRIDGE|50 research project. The project has been recently established in Italy to conduct a wide experimental campaign on the structural members of a concrete viaduct dismantled after a lifetime of about 50 years. BRIDGE|50 represents an example of joint cooperation among educational and research institutions, public authorities, owners and managing bodies, practitioners and other end users.

The preliminary activities already developed and the planned experimental program include photographic mapping of the structural elements, drone surveys, non-destructive diagnostic tests, full-scale load tests, and a large number of samples from the tested structural elements (concrete cores and samples of reinforcing steel bars and prestressing steel wires) for mechanical and chemical-physical tests. The results of the project are expected to provide knowledge advances for public authorities managing road networks and represent key information to improve existing criteria, methods, codes and standards for life-cycle design, assessment, inspection, monitoring, repair, strengthening, maintenance, and management of bridges and infrastructure systems.

Figure 17. Members of the BRIDGE|50 Research Project and Management Committee: Partners collaborating in the research include universities, public authorities, and private companies.

ACKNOWLEDGMENTS

BRIDGE|50 is a research project based on a research agreement among universities, public authorities, and private companies. Members of the Management Committee: S.C.R. Piemonte (President); Politecnico di Milano (Scientific Coordinator); Lombardi Engineering (Secretary); Politecnico di Torino; Piedmont Region; City of Turin; Metropolitan City of Turin; TNE Torino Nuova Economia; ATI Itinera & C.M. B.; ATI Despe & Perino Piero; Quaranta Group. The contribution to the preliminary on-site activities by Mattia Anghileri, Silvia Bianchi, Luca Capacci, Marco Cervio, Giuseppe Di Nunzio, and Ruiqi Luo from Politecnico di Milano, and Antonino Quattrone, Vincenzo Angilletta, Dario Varetto, Giovanni Bricca, Vincenzo Di Vasto, Angelo Nocilla, Stefano Di Domenico, Franco Grindatto, Paola Costa, Giuseppina Di Mauro, Luciano D'Elia, Luis Miguel Hernandez Ramos, Pierclaudio Savino from Politecnico di Torino, is gratefully acknowledged. BRIDGE|50 website: http://www.bridge50.org.

REFERENCES

Anghileri, M., Biondini, F., Rosati, G., Savino, P., Tondolo, F., Sabia, D., Manto, S., Nivriera, M., Trincianti, C., Ventura, D., Monti, G., Legramandi, C., Caruso, C., 2020. Deconstruction of the Corso Grosseto viaduct and setup of a testing site for full scale load tests. *Tenth International Conference on Bridge Maintenance, Safety and Management* (IABMAS 2020), Sapporo, Japan, June 28th-July 2nd, 2020.

ASCE, 2017. *Report card for America's infrastructure*. American Society of Civil Engineers (ASCE), Reston, VA, USA http://www.infrastructurereport card.org.

Beltrami, C., Bianchi, S., Cervio, M., Anghileri, M., Felicetti, R., Quattrone, A., Chiara, M., Salza, B., Masala, D., Bridge visual inspections: Experience of local authorities and the case study of the Corso Grosseto viaduct. *Tenth International Conference on Bridge Maintenance, Safety and Management* (IABMAS 2020), Sapporo, Japan, June 28th-July 2nd, 2020.

Biondini, F., Frangopol, D.M., 2016. Life-cycle performance of deteriorating structural systems under uncertainty: Review, *Journal of Structural Engineering*, ASCE, 142(9), F4016001, 1–17.

Biondini, F., Frangopol, D.M., 2018. Life-cycle performance of civil structure and infrastructure systems: Survey, *Journal of Structural Engineering*, ASCE, 144 (1), 06017008, 1–7.

Biondini, F., Frangopol, D.M. (Eds.), 2019. *Life-Cycle Design, Assessment and Maintenance of Structures and Infrastructure Systems*, American Society of Civil Engineers (ASCE), Reston, VA, USA.

Ellingwood, B.R., 2005. Risk-informed condition assessment of civil infrastructure: state of practice and research issues. *Structure and Infrastructure Engineering*, Taylor & Francis, 1(1),7–18.

Quattrone, A., Tondolo, F., Sabia, D., Capacci, L., Lencioni, A., Legramandi, C., 2020. Dynamic tests and modal identification of Corso Grosseto viaduct decks before the dismounting. *Tenth International Conference on Bridge Maintenance, Safety and Management* (IABMAS 2020), Sapporo, Japan, June 28th-July 2nd, 2020.

Savino, P., Anghileri, A., Chiara, M., Salza, B., Candiano, G., Quaranta, L., 2020. Corso Grosseto viaduct: Historical and technical overview. *Tenth International Conference on Bridge Maintenance, Safety and Management* (IABMAS 2020), Sapporo, Japan, June 28th-July 2nd, 2020.