TRUSS A Marie Skłodowska-Curie Innovative Training Network in the field of Structural Safety

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Marie Skłodowska-Curie Innovative Training Networks (ITNs) are a prestigious scheme funded by the European Union which aims to train a new generation of creative, entrepreneurial and innovative Early-Stage Researchers (ESRs), able to face current and future challenges and to convert knowledge and ideas into products and services for economic and social benefit[1]. A total 1161 proposals were evaluated as part of the H2020-MSCA-ITN-2014 call for a success rate of about 10.5%. The School of Civil Engineering in *University College Dublin* (*UCD*) is coordinating one of the 121 successful ITN proposals, titled TRUSS (Training in Reducing Uncertainty in Structural Safety, http://TrussITN.eu). TRUSS is a 4 year project with an estimated budget of €3.7 million that started on the 1st January 2015. Close to 40 per cent of the total budget is shared among Irish beneficiaries.

TRUSS consortium (Figure 1) consists of four leading European Universities (*University College Dublin*, *Trinity College Dublin*, *University of Nottingham*, and *Universitat Politècnica de Catalunya*), and five industry beneficiaries (*Ove Arup and Partners Ireland*, *Equipos Nucleares S.A.*, *Full Scale Dynamic Testing Ltd*, *Lloyd's Register EMEA* and *Phimeca Engineering*) that share expertise to produce research and training at an advanced level. Six additional industry partners (*Burgmann Packings*, *COMSA*, *Crack Ingenieria Catalana*, *Greenwood Engineering*, *Microlise Ltd* and *URS Infrastructure & Environment UK Ltd*) and one research institute (*TRL – UK Transport Research Laboratory*) provide specialised support in specific research projects. The consortium has international (5 European countries), inter-sectoral (Buildings, bridges, road, nuclear, wind turbine and marine infrastructure) and multi-disciplinary dimensions (Teams include civil, mechanical, chemical, electrical and electronic engineers, mathematicians, computer scientists and business and marketing managers). They cover advanced sensor-based structural health monitoring solutions (i.e., unmanned aerial vehicles, optical backscatter reflectometry, monitoring sensors mounted on vehicles traversing the infrastructure, etc.) and innovative algorithms for structural designs and short- and long-term assessments of infrastructure that support operators and owners in managing their assets.

[1] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/calls/h2020-msca-itn-2014.html

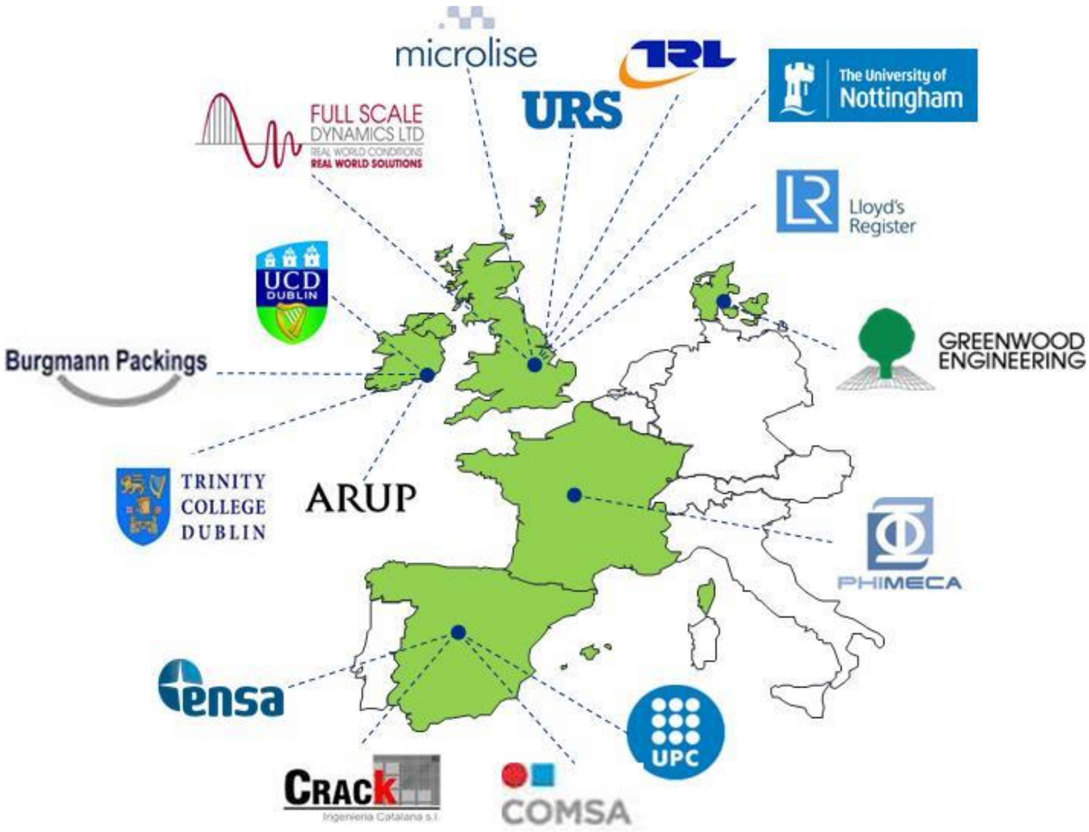

Figure 1 – Truss Consortium

A structure is deemed to be safe if the stresses due to the applied loads do not exceed the structural strength for the planned lifetime. In the calculation of stresses and strength, there is an unavoidable uncertainty associated to material properties, loads and response of the structure to these loads. TRUSS will quantify these uncertainties via complex modelling and analysis as well as measurements and monitoring of material strength, structural behavior and loading conditions. Innovative probabilistic approaches validated with theoretical simulations and experimental data will be used to produce an improved reliability analysis. The concept is illustrated in Figure 2.

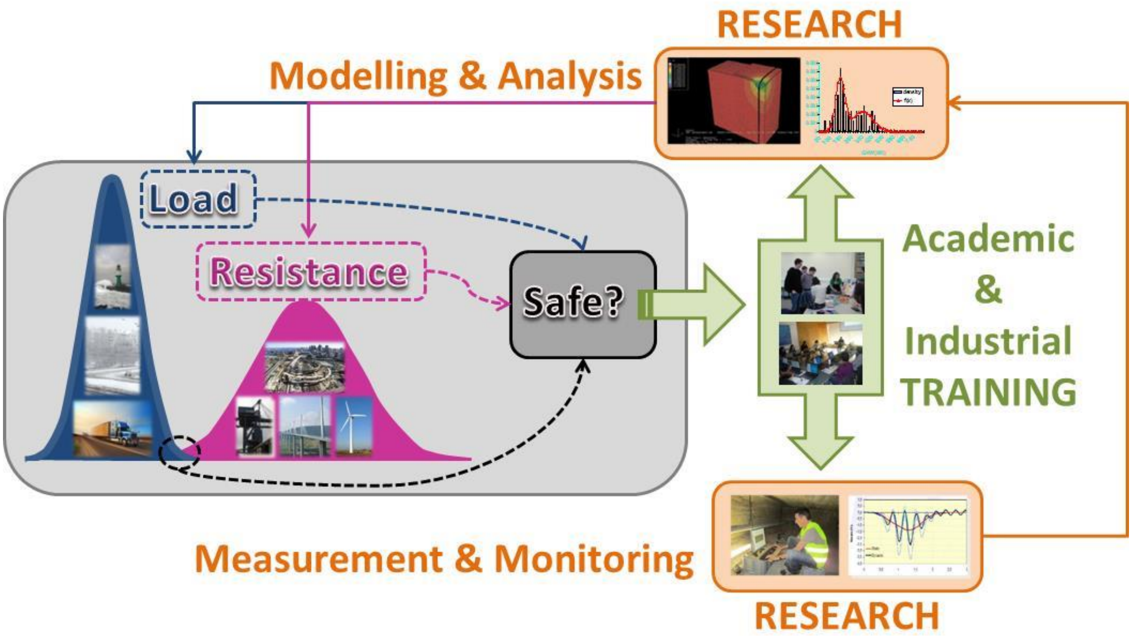

Figure 2 – Concept of TRUSS

TRUSS combines original and impactful research supported by secondments with local and network-wide training to give 14 graduate engineers significant insights and exposure to research and innovation in academia and in industry (Figure 3). In addition to scientific and technological knowledge, complementary skills (e.g. entrepreneurship, management and financing of research activities and programmes, management of intellectual property rights, other exploitation methods of research results, ethical aspects, communication, standardisation and societal outreach) are key components of the training. While developing tools that will reduce uncertainty in structural safety and improve infrastructure management, TRUSS lays the basis for an advanced doctoral programme that will qualify ESRs for dealing with the challenges of an aging European infrastructure stock, thereby meeting a critical need whilst at the same time enhancing their prospects for a career in both industry and academia.

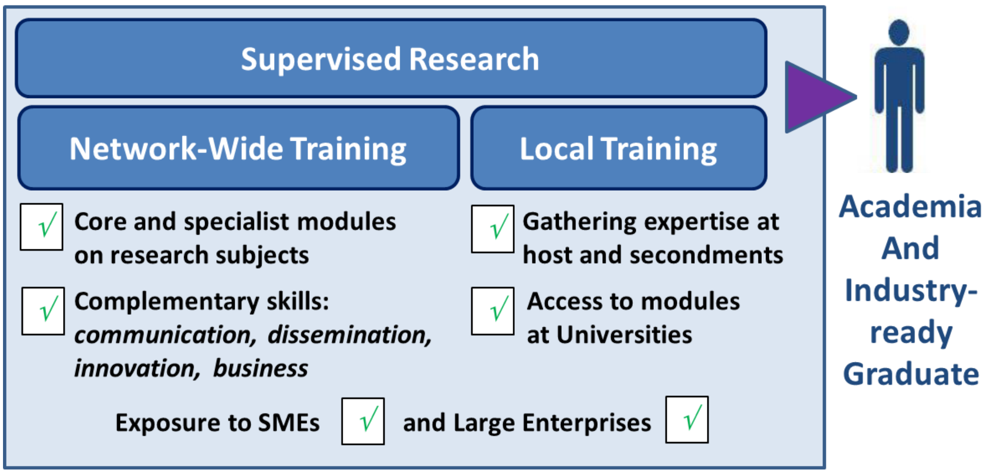

Figure 3 – Academic and Industrial Training

The research projects covered by TRUSS are listed in Table 1.

Table 1 – Individual Research Projects

Project Title	**Host**	**Country**
Reliability of concrete structures reinforced with braided FRP	*University College Dublin*	Ireland
Reduction of uncertainty in assessing concrete strength of existing structures	*Ove Arup and Partners Ireland*	Ireland
Reduction of uncertainty in design of free standing nuclear spent fuel rack	*Equipos Nucleares S.A.*	Spain
Probabilistic optimization of the design of offshore wind turbine towers	*Trinity College Dublin*	Ireland
Integrity management of ship structures	*Lloyd's Register EMEA*	United Kingdom
Residual life assessment and management of ship unloaders	*Lloyd's Register EMEA*	United Kingdom
Railway Weigh-In-Motion for bridge safety	*Full Scale Dynamics Ltd*	United Kingdom
Probabilistic modelling of bridge damage based on damage indicators	*Phimeca Engineering*	France
Railway bridge condition monitoring and fault diagnostics	*University of Nottingham*	United Kingdom
Assessment of bridge condition and safety based on measured vibration level	*Universitat Politècnica de Catalunya*	Spain
Development of optical fibre distributed sensing for structural health monitoring of bridges and large scale structures	*Universitat Politècnica de Catalunya*	Spain
Bridge damage detection using an instrumented vehicle	*University College Dublin*	Ireland
Using truck sensors for road pavement performance investigation	*University of Nottingham*	United Kingdom
Reduction of uncertainty through regularized, automated road inspection	*University College Dublin*	Ireland

The motivation behind three of the projects is described below as example of the research undertaken in Ireland.

- RELIABILITY OF CONCRETE STRUCTURES REINFORCED WITH BRAIDED FRP (Host: *University College Dublin*)

Considerable research has been conducted in recent years into the reliability of reinforced concrete structures subjected to time dependent changes in resistance and loading. The use of braided Fiber Reinforced Polymer (FRP) rebar (Figure 4) offers potential performance benefits as they are not subjected to the corrosion issues that frequently add uncertainty to reliability calculations. However the structural safety associated with this composite material is still not fully understood. FRP is an inherently brittle material, a feature that fundamentally changes the approach required in assessing reliability of structures manufactured using FRP rebar. TRUSS will propose models that will allow reducing the uncertainty associated to the response of Braided FRP. Experimental testing programmes at *UCD* (scanning electron microscopy and X-ray Photoelecton Spectroscopy, etc.)

planned in collaboration with *Burgmann Packings* will be utilised by the ESR to develop reliability models that will determine structural safety.

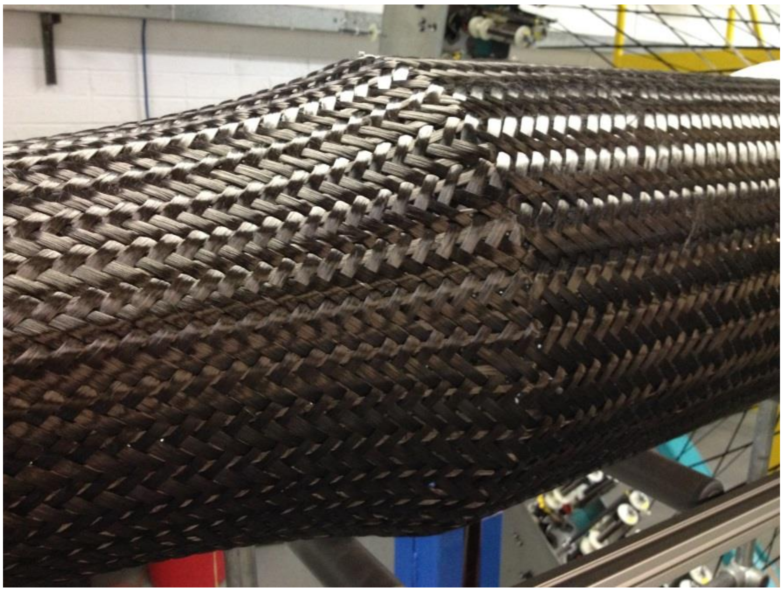

Figure 4 - Example of 20mm diameter triaxial braid FRP (Image courtesy of Burgmann Packings)

- REDUCTION OF UNCERTAINTY IN ASSESSING CONCRETE STRENGTH OF EXISTING STRUCTURES (Host: *Ove Arup and Partners Ireland*)

In 2013, the 8-storey Savar building in Dhaka-Bangladesh collapsed resulting in a death toll of more than 1100. This resulted in the deadliest garment-factory accident in history, as well as the deadliest accidental structural failure in modern human history. Following the collapse, the "Accord on Fire and Building Safety in Bangladesh" was established to maintain minimum safety standards in the Bangladesh textile industry. Nearly 1600 factories were covered by the Accord, representing around one third of the Bangladeshi textile industry. As part of the Accord, *Arup* was commissioned to carry out structural inspection on the factory buildings. The structural assessment of existing buildings requires the availability of information regarding the general arrangement of the structural elements with all the dimensions and the cross-section dimensions of all these elements. In addition, information about the loads applied to different parts of the building need to be assessed. Finally, the properties of the materials used in the structure have to be assessed. Among all the information required to carry out the structural assessment, the material properties proved to be the most difficult to assess. Accurate measurement of reinforcement inside the reinforced concrete members can be made with specialised equipment. At the time of constructing many of the textile factories in Bangladesh, concrete was hand mixed on site and due to the lack of natural gravel, normally using broken brick as a substitute, quality control was not tight and there is a lack of records on concrete test results from the construction time. All these factors resulted in a large strength variation of concrete strength, which needs to be accurately assessed on the basis of the existing structure. The objective of this project is quantifying the uncertainty in concrete strength assessment of existing buildings. A statistical correlation between tested and measured concrete strength of existing structures will be made based on existing methods and techniques (Figure 5). New methods will be suggested and compared to results on actual structures using existing methods.

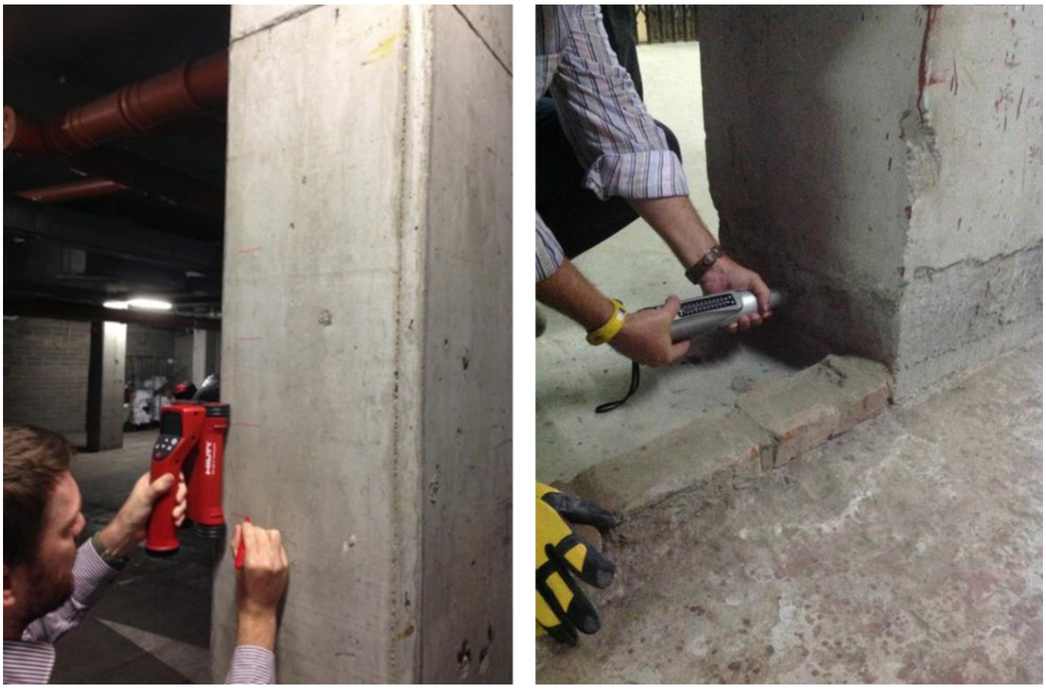

Figure 5 – Testing of Columns in Bangladesh (Image courtesy of Arup)

- PROBABILISTIC OPTIMISATION OF THE DESIGN OF OFFSHORE WIND TURBINE TOWERS (Host: *Trinity College Dublin*)

The growth of the global wind energy sector is undisputable with 215GW of installed capacity as of June 2011 (over 100 times the installed capacity of 1990). As the industry strives to innovate by reducing the unit price of wind generated electricity there is an ever-increasing requirement for research in this domain. Current models are rated up to 7.5MW with hub heights of up to 150 m. Due to the wind shear effect, taller hub-heights result in greater and more stable wind inflow speeds. Coupled with the fact that larger turbine units will generate greater amounts of electricity, this means that wind turbine sizes will tend to increase for the foreseeable future. As these hub heights increase, the size of the wind turbine units they support continue to get larger, wind farms are located in more severe offshore environments and in active seismic zones, the necessity to employ advanced design techniques, such as probabilistic methods, to optimize structural design becomes apparent. The objective of this project is to employ the principles of structural reliability theory and probabilistic analysis to optimize the design of offshore wind turbine towers considering possible combinations of extreme environmental loads such as wind and wave effects with natural hazards such as earthquakes. Overall the aim is to provide a methodology for the development of robust designs which minimize the risk to power supply interruption during the lifetime of the installation.

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