Executive Summary

EcoLanes’ main objectives are to develop, test and validate steel fibre reinforced concrete (SFRC) pavements that will contribute towards the strategic objectives of the thematic priority area of Sustainable Surface Transport. EcoLanes aims to use roller-compaction techniques (based on existing asphalt laying equipment) as well as recycled materials to reduce construction costs in the range of 10-20%, construction time by 15% and energy consumption by up to 40%.

The project, which started in October 2006, comprised 9 work packages: 4 RTD, 3 demonstration, 1 dissemination and 1 management. The project draws expertise from six European countries and its consortium (shown below) comprises four universities, three industrial partners, a Recycling Association and three end-users.

- The University of Sheffield, UK (Coordinator: Prof. Kypros Pilakoutas, Department of Civil and Structural Engineering, The University of Sheffield, Sir Frederick Mappin Building, Mappin Street, Sheffield S1 3JD, United Kingdom. k.pilakoutas@sheffield.ac.uk).
- Akdeniz University, Turkey.
- Technical University ‘Gheorghe Asachi’, Romania.
- European Tyre Recycling Association, France.
- Aggregate Industries UK Ltd, United Kingdom.
- Antalya Municipality, Turkey.
- Compania Nationala de Autostrazi si Drumuri Nationale din Romania, prin DRDP Iasi, Romania.
- Adriatica Riciclaggio e Ambiente s.r.l., Italy.
- Public Works Department, Ministry of Communications and Works, Cyprus.
- Cyprus University of Technology, Cyprus.
- Scott Wilson Ltd, United Kingdom.

In addition to the management and administration of the consortium, the following are the other main objectives for the third reporting period.

- Refinement / development of hardware prototypes that clean, sort and package the recycled steel fibres.
- Supply of steel fibre reinforcement required for the activities of the other work packages.
- Experimental and theoretical investigation of mechanical behaviour and durability of wet and dry SFRC mixes, which have reduced energy requirements and use recycled materials.
- Experimental and theoretical validation of the concept of the long-lasting rigid pavements (LLRP) made with wet and dry SFRC.
- Development of design guidelines for LLRP made with wet and dry SFRC mixes.
- Life cycle assessment of the environmental impact and cost of the demonstration pavements.
- Development of guidelines for producing LLRP made with dry SFRC.
- Design, construction, and monitoring of the four demonstration pavements made with dry SFRC.

The consortium had three management meetings during the period as well as several dissemination activities. On the RTD side, the main strategy during the 3rd reporting period was to tackle very quickly the areas that presented the highest technological risks, i.e. whether the recycled steel fibres could be supplied to
the project specification. The results from the fibre supply were positive, and that means that the overall project technological risks were eliminated. The performed work and main outcomes of the 4 main RTD work packages are as follows.

Work Package 1 – Fibre Sorting
The fibre cleaning and sorting techniques, developed during the 1st and 2nd reporting period, were optimised to increase the yield of useful recycled steel tyre-cord fibres (Figure 1a). This included refinement of the process and hardware used for the mechanical treatment of post-consumer tyres; during the 3rd reporting period, WP1 could produce (to the project specification) up to 500 kgs of recycled steel tyre-cord fibres per day. In addition, processes and equipment were developed for the 25kg packaging of the recycled steel tyre-cord fibres (Figure 1b). Specifications were also developed (for Q/A purposes) for the production and classification of recycled steel tyre-cord fibres; the latter comprises three classes: “SHEF Class A”, “EcoLanes Class B” and “EcoLanes Class C”. By the end of the project, around 105 tonnes of recycled steel tyre-cord fibres were supplied for the RTD and demonstration activities of the project.

Work Package 2 – Fibre Reinforced Concrete
Parametric studies were undertaken to assess the effect of key parameters on the fresh and hardened properties of dry SFRC. Experimental results indicate that the flexural behaviour of dry SFRC mixes, made with recycled concrete aggregates, is equivalent to the one obtained from SFRC mixes made with natural aggregates (e.g. Figure 2a). EcoLanes collaborated with the Federal University of Rio Grande do Sul (in Brazil) to investigate the fatigue flexural behaviour (e.g. Figure 2b) of selected dry SFRC mixes; the results show that dry SFRC containing 2% (by mass) recycled steel tyre-cord fibres has better fatigue performance than plain dry-concrete (at both low and high stress levels). Work was also carried out to assess the durability of selected wet and dry SFRC mixes; this work included corrosion and freeze-thaw tests as well as chloride ingress, permeability and porosity tests. Experimental results indicate that dry SFRC mixes are more susceptible to corrosion and freeze-thaw (e.g. Figure 2c) than wet SFRC mixes. However, these results may be due to the boundary conditions used in the specific tests.
Figure 2: WP2 experimental work: (a) Flexural behaviour of dry-consistency SFRC mixes made with recycled concrete aggregates, (b) Setup for fatigue bending tests, (c) dry-consistency SFRC samples after 28 days of freeze-thaw testing

Work Package 3 - Pavement testing, analysis and design

The trial SFRC pavement (Figure 3a), constructed and instrumented at the ALT LIRA facility, was tested under accelerated load testing; by the end of the 3rd reporting period, 1.5 million load cycles were accomplished. Results showed that there was no failure in any of the sectors, showing that (over a design life of 30 years) the proposed roads would survive at least 20.5 million-single-axis of traffic. In addition, extensive analytical and numerical (elastic and inelastic finite element) analyses of plain-concrete and SFRC pavements were undertaken (e.g. Figure 3b) to develop appropriate design tools and failure criteria for wet and dry SFRC pavements. Existing design methods for concrete pavements were examined and a design framework and software (Figure 3c) were developed for LLRPs made with wet and dry SFRC.

Figure 3 (a) Accelerated load testing of the trial LLRP at the LAT LIRA facility, (b) FE analysis of LLRPs, and (c) design software developed for LLRP made with wet and dry SFRC

Work Package 4 - Environmental studies and site processes

Guidelines were prepared for the production of pavements made with dry SFRC. Methodologies were also developed/refined for the life cycle assessment (LCA) of the environmental impact and cost of the LLRP and data was collected for the LCA of the demonstration pavements, constructed during the 3rd reporting period. For comparison purposes, LCA was also undertaken for four alternative pavements (asphalt and three made with wet concrete). In addition, a parametric study was undertaken to examine the effect of key parameters on the LCA of pavements made with wet and dry SFRC. LCA results indicated that the energy consumption of SFR-RCC pavements can be up to 40% less than that of the commonly constructed asphalt pavements. In addition, it was determined that the life cycle cost of dry SFRC pavements can be lower than that of wet SFRC and asphalt pavement. It was also evaluated that the environmental and cost impact of dry SFRC pavements improves as the fibre content increases (due to the reduction in the pavement depth).

On the demonstration side, activities included design, construction, and monitoring of the four demonstration pavements. The WP5 demonstration pavement (Figure 4a) was constructed in London (UK) and comprised a series of access channels (surface area 300 m²), subjected to heavy goods traffic. The
pavement was constructed in April 2009 and was made with dry SFRC containing 5% (by mass) recycled steel tyre-cord fibres. The WP6 demonstration pavement (Figure 4b) was constructed in Gura Humorului (Romania) and comprised full rehabilitation of an existing heavily-trafficked road (150 m long, 9.5 wide). The pavement was constructed in May 2009 and comprised two sectors: one made with dry plain concrete and one made with dry SFRC containing 3% (by mass) recycled steel tyre-cord fibres. Two demonstration pavements were constructed by WP7 in April 2009. The first WP7 demonstration pavement was constructed in Antalya (Turkey) and comprised full rehabilitation of an existing urban road (150 m long and 8.6 m wide), subjected to heavy daily traffic. The pavement comprised three sectors: one dry plain-concrete, one dry SFRC containing 2% (by mass) industrial fibres and one made with dry SFRC containing 3% (by mass) recycled steel tyre-cord fibres. The second WP7 pavement (40 m long, 6 m wide) was constructed in Pafos (Cyprus) and comprised rehabilitation of a rural road, subjected to ground movements. The demonstration pavement was placed over the existing asphalt road to maintain the geotechnical equilibrium and was made with dry SFRC containing 2% (by mass) recycled steel tyre-cord fibres. “EcoLanes Class B” recycled steel tyre-cord fibres were used for the construction of the demonstration pavements; in addition, a thin asphalt overlay was placed over all pavements.

Figure 4 – Demonstration pavements: (a) UK, (b) Romania, (c) Turkey, and (d) Cyprus

The consortium also undertook dissemination activities, such as publication of 46 press releases and 36 technical papers. Three industrial seminars were also held (May 2007 in Rome, Italy, October 2008 in Iasi Romania and April 2009 in Pafos Cyprus).

Outcome

A number of results were produced from the work of the EcoLanes project.

- The project has developed small to medium scale industrial processes and machinery for sorting the steel tyre-cord fibres.
- The project developed SFRC mixtures, which use materials with low energy requirements.
- Analysis and design software were also developed for the concept of LLRP.
- Methodologies were also developed for the LCA of LLRPs made with wet and dry SFRC.

These results should provide: a) a sustainable market for the steel fibres recycled from post consumer tyres and, thus, encourage the material recovery of large amounts of tyres, b) open the way for the construction of LLRP, which are more economic and environmentally friendly.

The EcoLanes consortium has also developed an exploitation strategy of the project. Further information on the EcoLanes’ activities and dissemination material may be obtained from http://ecolanes.shef.ac.uk.