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Recycling practices for airport pavement construction: Valorisation of on-site materials

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HIGHLIGHTS

- Mechanical performance and environmental impacts of recycled airport pavements were evaluated.
- Laboratory and full scale investigations were conducted.
- Environmental savings due to recycling practices respect to a standard asphalt pavement were analyzed.
- Recycled pavements totally complied to the airport needs in terms of bearing capacity.

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ABSTRACTS

Environmental sustainability in transportation infrastructures can be achieved by using recycled materials. Commonly, road and airport pavement construction is identified as a greatly polluting factor for greenhouse gas and odor emissions. This paper presents a case study concerning two rehabilitation methods adopted in a reconstruction project of two taxiway pavements in a major Italian airport. The paper describes the entire process of rehabilitation works starting from the preliminary investigations to the final quality controls. It includes the pavements design phase and the materials optimization and environmental assessment, which is the core of the research. The findings show that recycling does not necessarily result in lower performance. In fact, up to 65% of CO_2e emissions were saved by constructing the recycled pavements. Performance was instead comparable to a standard asphalt pavement. Finally, the paper shows the eco-efficiency of including low-energy treatments and sustainable strategies into pavement construction to enhance environmental savings and cost effectiveness in airport construction practices.

1. Introduction

Sustainability is a main current theme for pavement management operators worldwide. Major sources of air pollution associated with airports and air transport concern noise and gaseous emissions, typically related to airplane operations and construction (or maintenance) activities of airfield infrastructures.

More precisely, the environmental impact of pavement construction and maintenance is becoming increasingly important due to their large extension. Valuable and non-renewable natural resources are indeed widely consumed every year for the construction and reconstruction of pavements. Maintenance plans of airport pavements also involve large amounts of waste materials mainly coming from end-of-life pavements, which generate environmental burden due to their transport to landfill and disposal. Instead of consuming virgin materials, recycling helps to ease landfill pressure and reduces the demand for rocks extraction in order to guide the pavement construction technique towards the sustainable path.

At present, current research focuses on reuse of waste materials, such as concrete aggregates, to be predominantly adopted in the lower pavement layers (sub-base and foundation layers). For instance, Giustozzi [10] presented the construction of a recycled airport pavement by evaluating both the performance and the environmental assessment of materials adopted. The environmental analysis showed a saving of 35% of CO_2 equivalent emissions during the construction phase.

However, great mechanical performance and long-term durability are also essential factors in airports due to the heavy loads and the small time for pavement maintenance [1].

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This paper presents the case-study of the construction of two taxiway pavements in a major Italian airport located in the northern part of Italy. The optimization of resources and the balance between pavement performance and the environment was included into the design and construction phases. The use of recycled material, which provided less carbon emissions and reduced process-energy, was defined as to be the main project feature. Recycling allowed for reusing existing construction materials, limiting handling to/from the construction site and increasing the efficiency of construction operations. Thus, intervention time was reduced by avoiding traffic delays and airport capacity reduction and allowing a swift re-opening to the traffic. More than 70% of the total amount of the construction materials was obtained by crushing and sieving the concrete slabs of the on-site old pavement or by using on-site stabilization techniques. The paper also describes the entire process of rehabilitation works from the preliminary investigations to the final quality controls including the pavements design stage, materials optimization and environmental assessment, which is the core of the research. Results showed how it is possible to obtain high-performance airport pavement by taking into account the carbon footprinting of the construction works and by saving natural resources through the adoption of recycled materials.

2. Literature review and research goals

Sustainable development is the preservation of a long-term continued production capacity of natural resources in an economically feasible way, which must be socially and environmentally acceptable. For this reason, various practices have been proposed in the last years for sustainability in aviation. International Civil Aviation Organization (ICAO) developed a range of standards through integrated measures. These include the introduction of aviation biofuels and engine emissions reduction (i.e. fleet modernization, improved flight planning and management), conserve and use of renewable resources (solar energy, for instance), improved airfield design for energy efficiency (resulting in minimizing building energy loss), recycling practices and waste management, etc. Oto et al. [19] sought to establish aviation environmental research needs and critical issues by defining six main environmental targets to investigate. These targets are process, tools, technology, water, air, and noise.

Waste materials, such as old concrete slabs or disposed asphalt pavements, are frequently named "resources in the wrong place" [6]. However, as many airport pavements are approaching their service life, the demand for the use of recycled pavements is rapidly rising [20]. Furthermore, scarcity of quality aggregates, environmental protection policies and increasing costs of asphalt binder demonstrate how eco-effective and economical it can be to improve pavement management practices on roads and airfields by implementing recycling.

Several studies were conducted in the last few years to characterize the properties of recycled pavements. Mills-Beale and You [17] evaluated the potential of using Recycling Concrete Aggregates (RCA) in Hot Mix Asphalt (HMA) for the construction of roadways where traffic load is minimal (rate of 25, 35, 50 and 75%). Results indicated that the tensile strength properties of the mix were preserved along with the possibility of significant energy savings during the compaction process. This is due to the increasing of RCA. In fact, as the RCA decreases by 50%, the Construction Energy Index (CEI) [3] decreases by 65%. CEI measured the energy required to compact the mixture to the specified density. The lower the CEI value, the lower is the energy involved. Giustozzi et al. [9] found that 82% of emissions during construction can be saved when the stabilization of on-site soils is applied to road foundation layers and it therefore represents an ideal opportunity for contractors and companies to reduce their environmental impacts when building pavements.

Marie and Quiasrawi [16] considered three different types of asphalt mix. The first one was conventional HMA, made by 100% virgin aggregates. The second one included 20% of RCA. The third one was obtained by recycling the previous mix and reusing 20% of RCA (Recycled RCA, R-RCA). They discovered that R-RCA showed higher compressive and indirect tensile strength than RCA, but still lower than control HMA (decreasing of 20% and 12% for compressive strength and decreasing of 10% and 5% for indirect tensile strength). Furthermore, workability decreased of 30% for the first generation of RCA and 12% for R-RCA. Thus, both the last two mixes indeed provided higher absorption than the first one.

Hou and Ji [12] used waste cement concrete collected from a bridge demolition to design four different mixes with different RCA content: 0%, 30%, 60%, and 100% by the total weight of aggregates. They found that the voids and micro-fractures in RCA provided larger water absorption and a reduction of density and strength, while the application of activator decreased the previous values and enhanced adhesiveness to asphalt. Agrela et al. [2] assessed that reusing recycled aggregates affected compressive strength, stiffness, creep or shrinkage, and suggested that coarse aggregates should be adopted in the mix.

Given the literature mentioned above, the main goal of the present study was to contribute to the existing knowledge related to the use of recycled materials in airport pavements. To this end, two real scale rehabilitation works were considered. The research was oriented toward the assessment of:

- the advantages of the use of recycled materials in terms of carbon footprint; A complete environmental characterization of the rehabilitation works was indeed performed and the results were compared to the environmental burden associated to a standard asphalt pavement, commonly adopted by the local airport authorities.
- the suitability of recycled pavements for the heavy airport traffic, including the NLAs (New Large Aircrafts) such as the Airbus 380 and the Boeing 777. A description of the design and construction processes of both pavements is reported in the paper.

3. Preliminary investigation

The airport constituting this case study has two parallel runways and several taxiways, as well as two main aprons; the entire airport area is about 12.5 km^2. The taxiways that had to be reconstructed were between 40 and 50 years old and were originally built by adopting a concrete slab top over a cement bound subbase layer. Some maintenance interventions had been conducted over the years of operations through a partial milling of the slabs and asphalt filling (generally 4–5 cm). It should be pointed out that this operation did not involve the entire pavement assets but only isolated spots in need of emergency maintenance, as a result of the occurrence of strong deterioration. These interventions guaranteed adequate values of smoothness and friction but did not include the structural deterioration of the pavement, which was due to the slow heavy traffic. Taxiways exhibited aging phenomena and fatigue cracking. In addition, the infiltration of storm water caused the fall of the pavement bearing capacity. This was due to differential displacements, loss of support from the bottom layers, and reflective cracking on the surface layers.

Fig. 1 shows the pavement distresses before the renewal intervention, clearly demonstrating the end of the service life of the concrete slabs. Other surface distresses were also identified: transversal and longitudinal cracking, joint spalling and faulting, and several corner breaks. According to the field distress survey,