

# Carpet waste utilisation, an awakening realisation: A Review

M. Mirafteb and M. Mirzababaei; University of Bolton, Centre for Materials Research and Innovation, Bolton BL3 5AB, UK.

## ABSTRACT

Waste generated from pre-and-post consumer waste is becoming a concerning issue both with the manufacturers and the disposal authorities. Light-hearted attitudes of carpet manufacturers towards waste less than a decade ago are rapidly changing as burden of storage, transportation and disposal costs are biting into company budgets. This review paper will explore waste generation and its accumulation from source to end-product and highlights some of the innovative approaches adopted by manufacturers, researchers around the world and in particular those attempted by University of Bolton.

## Introduction

Waste, in all shapes and forms, is the world's biggest environmental challenge in the 21<sup>st</sup> century. Its long-term impact on everyday life can neither be ignored nor dismissed as it gradually manifests itself on the quality of life we lead, be it the water we drink or the air we breath. Amount of overall waste disposed into landfills in UK have been alarmingly high. On average, over 330 million tonnes are sent into landfill each year<sup>(1)</sup>. Majority of this waste is classed as construction and mining waste but about a third is associated to household, commerce and industrial waste. Just over 60% of household or municipal waste is considered as biodegradable waste, the rest includes glass, metal as well as plastic and textiles. The chart below (Figure 1) shows the estimated proportional representation of waste within UK in 2004<sup>(2)</sup>.

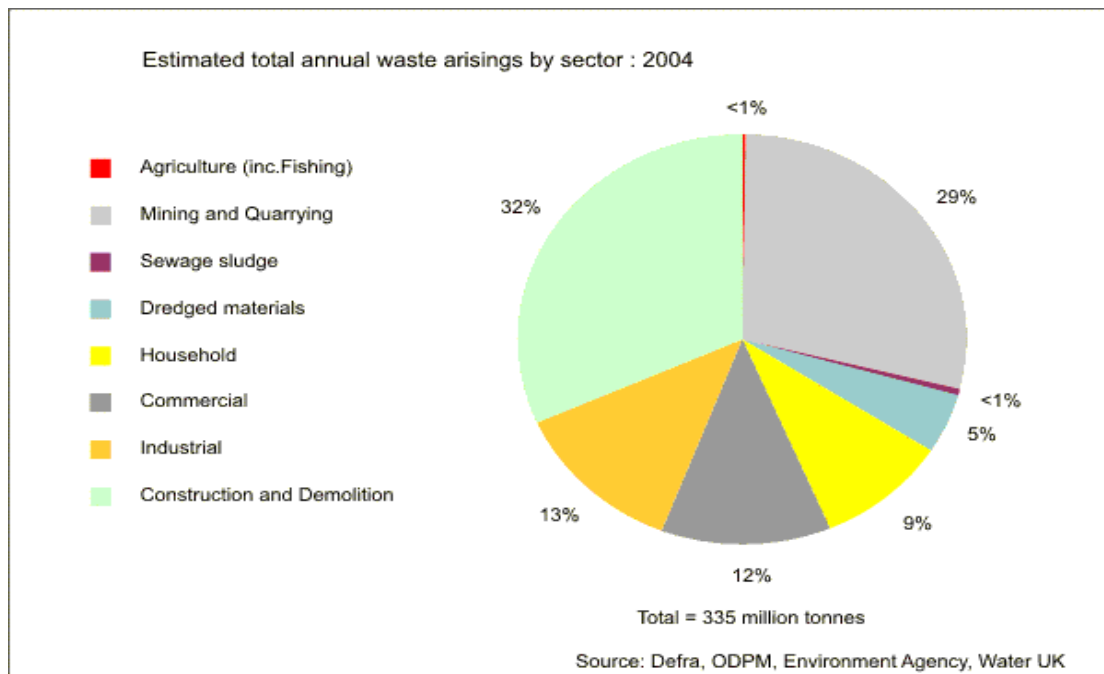


Figure 1: Estimated total annual waste arising by sector

Given that there are now very limited numbers of landfill sites in UK i.e. 1500<sup>(3)</sup>, the pressure to reduce biodegradable and non-bridgeable waste is mounting. Figures

released in 2008 by the Department of Environment, Food and Rural Affairs (Defra) suggest a change in individual habits and an increasing trend towards recycling following greater public awareness and the nationwide investment in collection regimes and waste processing. The chart below (Figure 2) shows the amount of waste per person generated between 1996 to 2008 and the relative proportion that is gradually being recycled or composted.

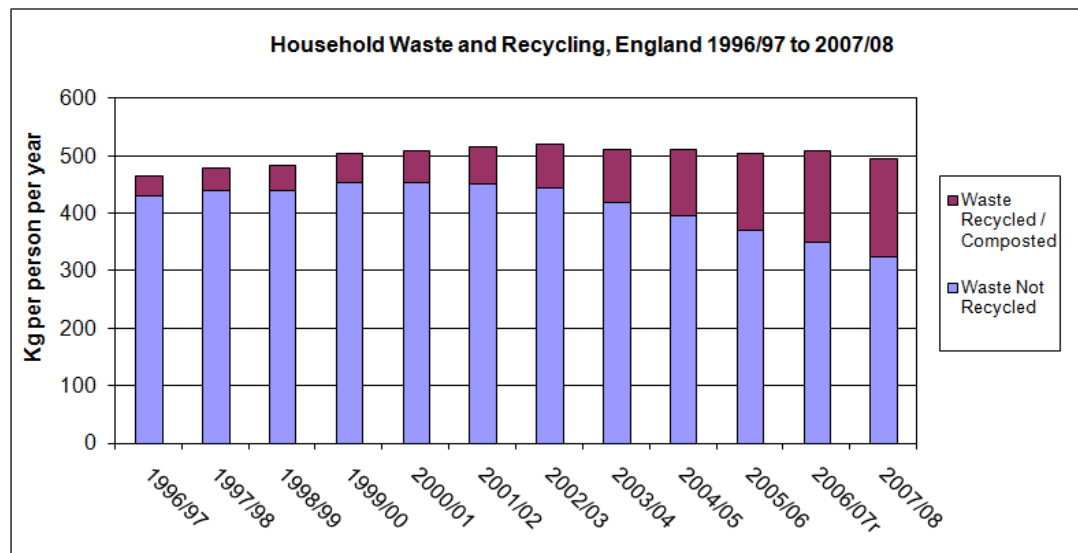


Figure 2, Municipal waste management statistics 2007/08, Source: Defra.

In 2008, total municipal waste collected in UK, according to the report, reduced from 29.1 million tonnes in 2006/7 to 28.5 million tonnes in 2007/8. The average annual change in municipal waste over the past five years to 2007/08 was a decrease of 0.6%.

In total, 45.1% or 12.9 million tonnes of this waste had some potential value whether through recycling, composting or similar means i.e. a rise from 41.8% (12.2 million tonnes) in 2006/7. Encouragingly, the proportion of municipal waste being dumped into landfill has steadily continued to decrease from 57.9% in 2007/7 to 54.4% in 2007/8. In 2008 only 15.5 million tonnes found its way into landfill.

The downward trend in landfill dumping is due to a number of factors including:

- Better and more efficient collection setups and sorting means by the local authorities and emergence of recycling plants
- Hefty increases in landfill taxes i.e. landfill tax in 2007/8 increased from £16 per tonne to £24 per tonne and will continue to increase at this rate i.e. £8 per year in 2008/9 and 2009/10.
- Pressure brought about by European Union Directive regarding landfill waste. The directive is aimed at cutting the amount of waste ending up in landfill sites by 35% of that produced in 1995 (i.e. 29 million tonnes) by 2020.

Despite these efforts, UK is still far behind with recycling in Europe. The chart below (Figure 3) shows <sup>(4)</sup> the total waste generated per head in 15 European countries and the corresponding proportions that are recycled. As can be seen from the chart, Netherland, Germany and Austria have established recycling technologies most

effectively where as UK, Portugal and Greece are still far behind. UK average recycling efforts is well below the European average.

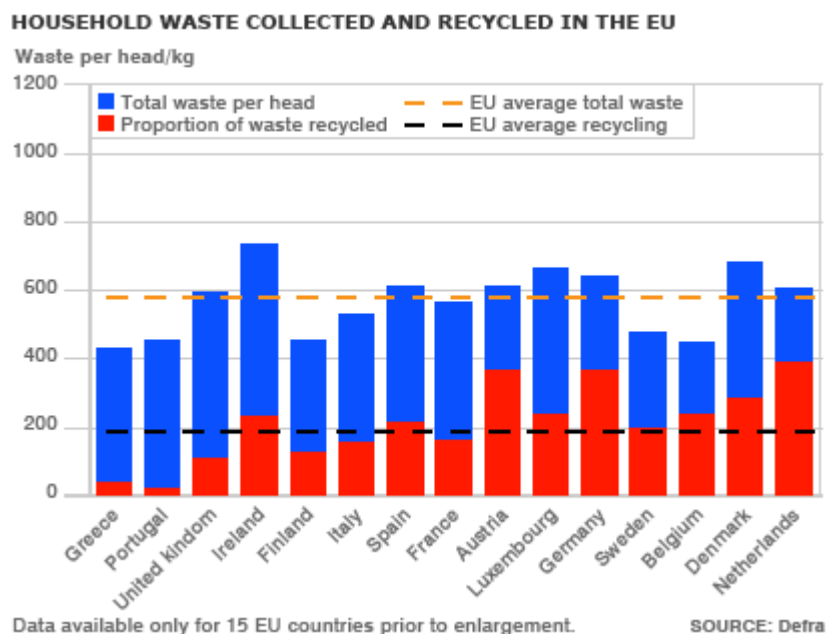


Figure 3, Household waste collected and recycled in the EU

Textiles account for 2-5% by weight of all waste that end up in landfills, carpets being the heaviest commodity in this sector are hence most affected. On average, a typical UK carpet manufacturer produces 15 tonnes of process waste per week. Although the number of carpet manufactures in UK have reduced in recent times but this still accounts for a considerable amount of collected waste. The estimated post-consumer carpet is in the region of 500,000 tonnes per year. With the big jump in landfill taxes in the past two years, there has been a notable surge in activities of manufacturers seeking to reduce their waste at each stage of manufacturing and/or utilise the inevitable waste in one form or another.

### **Carpet waste and recycling**

Carpets are compact composite structures often made from a number of materials that are difficult, if not, costly to separate and reprocess. Consequently, the most convenient route has traditionally been the landfill option. However, this is becoming increasingly impractical given the associated costs and the physical limitations in numbers of available landfill sites. Furthermore; toxic emissions due to material decomposition and contamination in general, are other issues forcing people away from this practice. The second most popular option has been burning or incineration. The calorific outputs from incineration of synthetic-based carpets, in particular, match those of petrol and diesel. Sweden and Denmark have been in the forefront of utilising energy generated from incineration to boost heat and power facilities at local and industrial levels for at least the past twenty years. Netherland, Germany and France also use incineration as a means of generating power and energy. However, such practices remain controversial given the emission of toxic gases and dioxins resulting from molecular breakdowns<sup>(5)</sup>.

Recycling has been a long tradition in the textile industry where old clothes and unwanted fashion items have often found users through charities or other similar organisations. Surplus, shoddy fibres and off cuts from spinning mills and manufacturing units have also found an established route to furniture industry as fillers and subordinate components. Carpets, however, being the single most important commodity in terms of weight per unit area and high cost of production are much more difficult to deal with and often end up in landfills. Post consumer carpets are particularly bad given their greater available volume and their associated environmental hazards caused by contamination and dirt contents.

### **Recycling methodologies**

Over the past twenty years or so there have been many attempts to address the issue of carpet waste. One of the earliest attempts goes back to separation and depolymerisation of contaminated nylon 6, followed by its re-polymerisation into virgin material. Following early small scale productions in its early days, DSM and AlliedSignal inaugurated the worlds' first fully commercial nylon 6 recycling plant in January 2000 in Georgia. Nylon 6 regeneration, although highly effective and feasible, it can also be a costly process.

When dealing with carpet processing waste and rejects, the problem is often separation of the face fibres from the backing and elimination or separation of the secondary backings including possible additives e.g. jute, polyurethane, PVC, bitumen, fillers etc. A physical separation often involving shearing or cropping of the pile fibres is relatively easily achieved, but pile fibres often account for only a 1/4 or a 1/3 of all the weight of the carpet and the remainder is often land filled. The situation is even worse when post-consumer carpets are considered for recycling. Post-consumer carpets need to be collected from different locations, sorted according to materials' contents and physically cleaned or decontaminated from all dirt. A highly costly process before anything useful, that might eventually be done to the waste.

Georgia Tech has been in the forefront of finding alternative means for dealing with carpet waste. Their work is widely publicised and will not be regurgitated in this review <sup>(6)</sup>. However, briefly, they relate to utilisation of fibrous waste in composites and laminated structures, in plastic resins, injection and press mouldings as well as inclusion into soil and concrete. Other attempts to utilise carpet waste include synthetic fuel pellets <sup>(7)</sup> as source of heat and pure wool pellets used as natural fertilisers for plants.

### **Carpet waste projects at Bolton**

Over the past ten years or so, research at Bolton, has included carpet waste analysis and study of its utilisation potentials in different disciplines where carpet waste could be used based on its inherent merits without necessarily incurring heavy costs. Initial works began by considering clean carpet tile wastes that were locally generated by Milliken Carpets based in Wigan, U.K. The PVC backed nylon carpet tiles were granulated to various sizes and co-blended with different binders with the expectation of generating flexible, resilient and a durable product that would serve as an underlay, usually laid down before a carpet or laminate floorings are fitted. An optimised version of this product following various tests in accordance with British Standards

for underlay flooring was developed. This was then further refined and exploited for its acquired acoustic properties. It was discovered that if the granulated entities could be strategically reduced in size and proportional ratio of the backing/fibrous mass could be controlled respectively, the combined effect would lead to acoustic properties that would match commercially available acoustic materials at a fraction of the price <sup>(8,9)</sup>. Figure 4 (a-c) show comparative impact test results of 15 commercial acoustic barriers against the developed optimised acoustic underlay, U2. The results show that the impact sound reduction capability of the waste-based underlay, U2 is similar to majority of these commercial products and, in some cases, appears to be considerably better. Some of the commercial samples performed better than U2 by up to 10 dB, especially at lower frequencies. The Acoustilux 5518 test specimen in particular, transmitted impact sound levels ~20 dB lower than U2 at low frequencies, but this is probably due to thicker construction of Acoustilux 5518 i.e. 15mm as opposed to 10mm thickness of U2. It is also worth noting that the density of the recycled underlay sample U2 is also comparatively low compared with the densities of commercial underlays. This could be a potential advantage where lightweight applications are required.

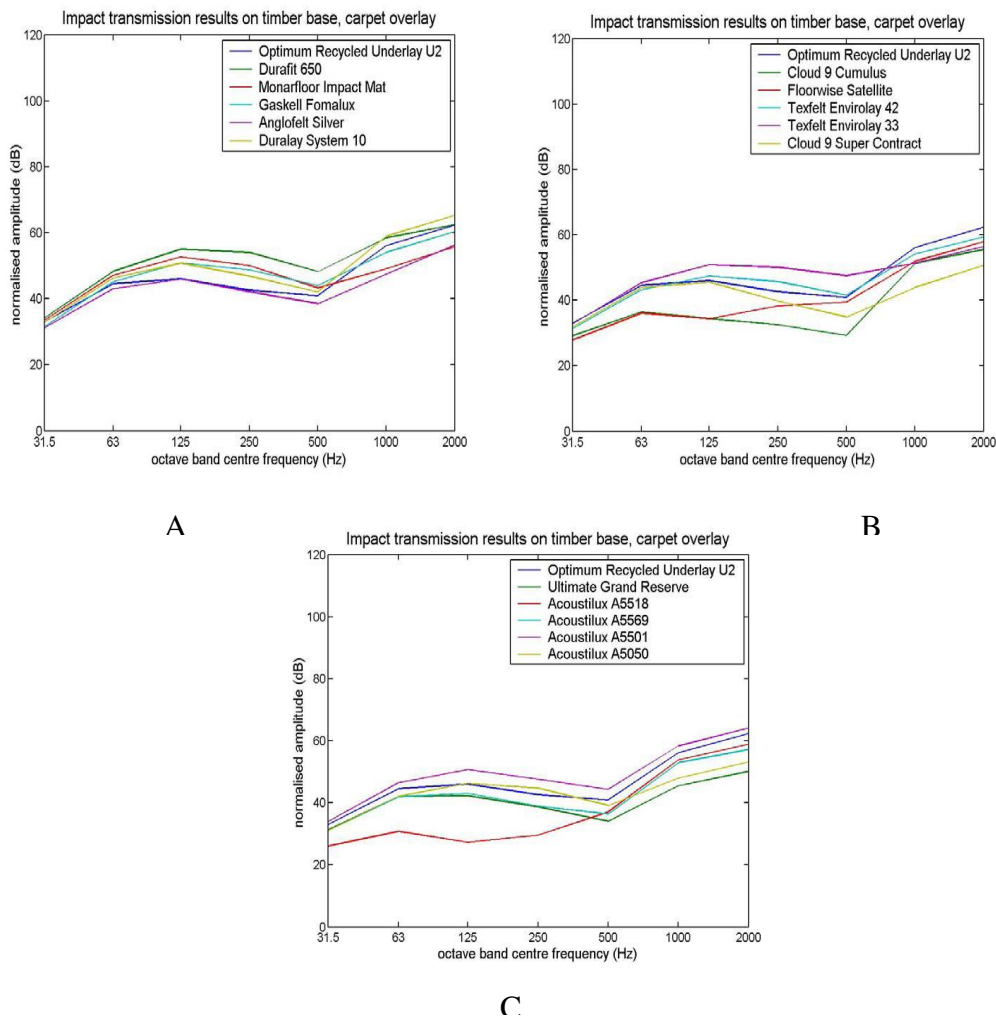


Figure 4 (a-c) Comparative impact test results of 15 commercial acoustic barriers against the developed optimised acoustic underlay, U2

Ten commercial underlay products designed for use with laminate flooring systems were also tested on the impact rig under a 8mm-thick piece of laminate, and a similar comparative assessment was made of their performance against sample U2, Figure 5 (a-b). U2 sample performed better than most commercial underlays, although, the U2 sample was thicker than the standard laminate flooring underlays. The multilayered Texfelt LamiMate was the only underlay that reduced impact sound more than U2.

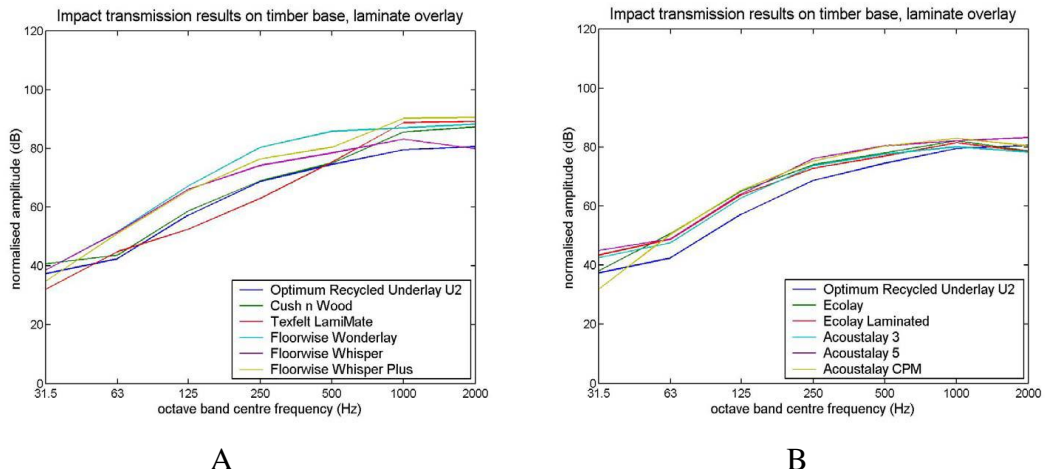


Figure 5 (a-b), Comparative impact test results of 10 commercial acoustic barriers and U2 versus laminate overlay.

Airborne sound transmission is another means by which the developed U2 samples were assessed. Figure 6 shows comparative results of timber against U2 and two commercial products at different frequencies.

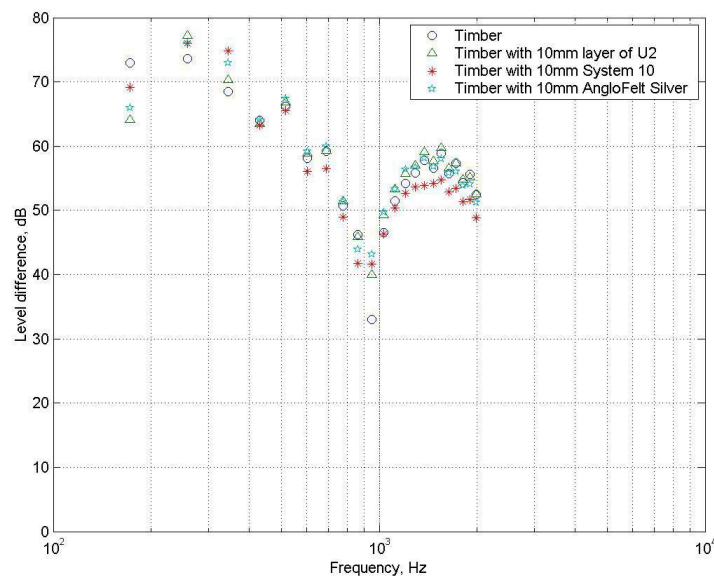
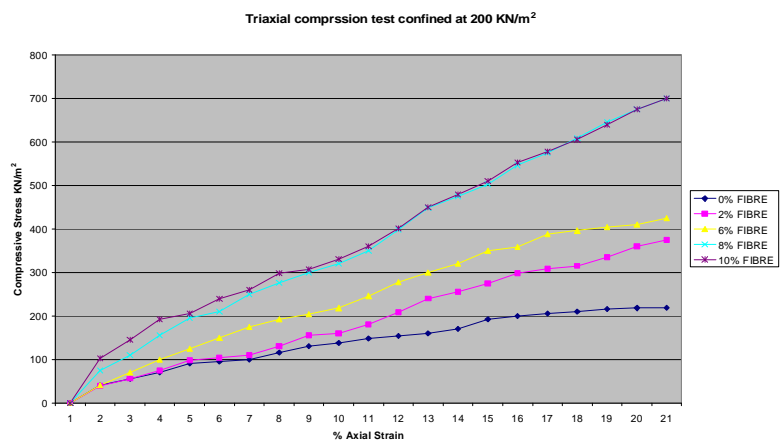


Figure 6, Comparative results of timber against two commercial products and U2 sample.

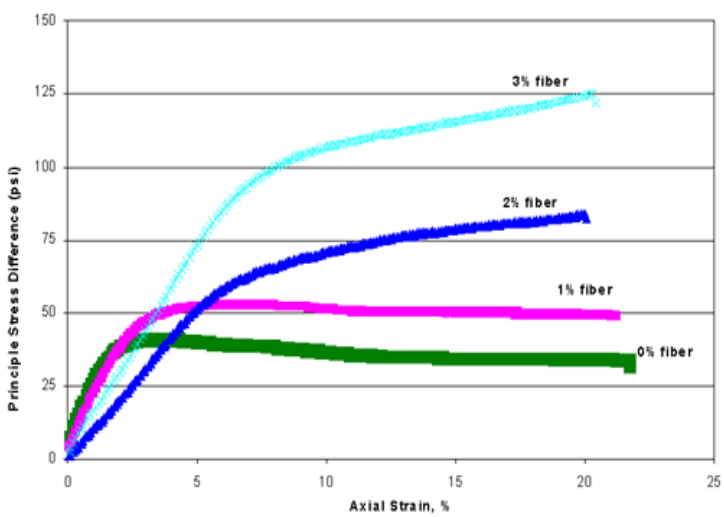
It can be seen that sample U2 and the commercial underlays contribute up to 10dB of transmission loss, depending on frequency. The recycled underlay sample, U2 is

highly porous and has low flow resistivity. The commercial samples all have a carrier backing which increases their flow resistivity. However, the airborne transmission loss of U2 could be increased during commercial production if the uncured U2 formulation mixture is applied to a high flow resistivity backing or scrim.

The second piece of research work at Bolton has looked at the feasibility of including short nylon fibres resulting from shearing or cropping of carpet pile yarns into clayey soils. These investigations have shown somewhat controversial results compared to similar works carried out at Georgia using different carpet waste fibres. Figure 7(a-b) show comparative maximum allowable fibre content under triaxial test for these different sets of investigations<sup>(6,10)</sup>. To investigate these findings at a greater depth and identify the role fibre waste geometry and configuration play in clay consolidation and reinforcement, further work are currently being carried out at Bolton<sup>(11)</sup>.



A

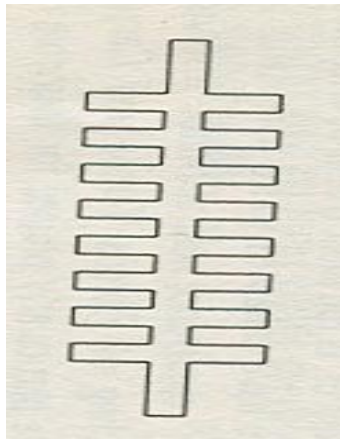


B

Figure 7(a-b), Comparative maximum allowable fibre content under triaxial test, B from Wang et al<sup>(6)</sup>

Finally, interest in possible use of carpet waste in containment of concrete blocks after

receiving sudden impacts or vibration tremors such as those experienced in a bomb blast and/or an earthquake led to the next project at University of Bolton <sup>(12)</sup>. Although much work remains to be done, initial investigations has shown that inclusion of suitably shaped tufted carpet wastes into concrete blocks would help to contain and subdue shattered pieces in the event of a sudden impact or such like releases of energy e.g. bomb blast or an earthquake. Figure 8 (a-c) show the typical insert and an example of its containment once placed in a concrete block and subjected to repeated blows from a sledge hammer. Figure 8c shows the unravelling of tufted yarns after experiencing a three point test and a tensile extension.



A



B



C

Figure 8 (a-c), (a) example insert, (b) impacted block with insert and (c) three point test followed by tensile extension.

### **Conclusion**

Waste, as a by-product of what is manufactured will always exist. The challenge in the 21<sup>st</sup> century is, first and foremost, to reduce its creation at source; by designing manufacturing machineries that avoid or reduce waste generation along the entire production and processing route. Second, select raw materials that are chemically compatible and conformable to the required needs thus making them easy to recycle and regenerate without the pain and costs of sorting and separations. Third, improve recycling technologies and promote application of waste-based products in new and novel areas of engineering such that the current “second grade” public perception of recycled materials and goods are changed into a forceful statement of pride, environmental consciousness and generally, a “green” and a “cool” thing to do.

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