UTILIZATION OF SHREDDED TETRA-PAK IN HOT MIX ASPHALT

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ABSTRACT

The growth in various types of industries together with population growth has resulted in enormous increase in production of various types of waste materials, world over. The creation and disposal of non-decaying waste materials have been posing difficult problems in developed as well as in developing countries. The efforts to find useful applications of some of the waste products in highway construction have given encouraging results.

The use of Tetra-Pak (TPA) containers to pack food of various kinds including milk, juice, meat, etc. has become a common practice. To produce packaging materials, TPA uses paperboard (73%), plastic (22%) and -for aseptic packages- aluminum foil (5%). However the disposal of the Tetra-Pak in large quantities has been a problem and is of great concern, particularly in big cities. In case it is possible to find useful application for the waste TPA, there will be substantial scrap value for this waste product and therefore they will be collected and sold by interested persons, instead of being littered or thrown out in the dust bins or into the road side drains.

The present study investigates the benefits of using shredded Tetra-Pak in binder layer flexible pavement mix. A (1-6)mm in particle pieces of TPA had been added. The mix had been tested by Marshall testing method. Mix volume relationships, Marshall Stability and flow with the different percent of shredded TPA were recorded.

A control binder mix is used with (5)% asphalt content for comparison and the same asphalt content used for all specimens. The research concluded that using TPA in the range of (1-1.5)% in HMA increase the Marshall stability, flow and air voids and decrease in voids filled with asphalt. For (2)% there was decrease in stability, air voids and voids filled with asphalt (VFB) and increase in flow. In (3-above)% the mix start scattered in the test.

استخدام علب (Tetra-Pak) المقطعة في الخلطات الاسفلتية الساخنة

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ملخص البحث

النمو المضطرد لمختلف الصناعات إضافة للنمو السكاني عالمياً سبب زيادة في كثير من أنواع المخلفات. الانتاج والتخلص من هذه المخلفات وخاصة غير القابلة للتحلل يعتبر مشكلة في كثير من الدول وخاصة النامية منها. وايجاد طريقة لاستخدام جزء من هذه المخلفات في مجال هندسة الطرق اعطى نتائج مشجعة.

استخدام علب (Tetra-Pak) لحفظ مختلف الاطعمة مثل الحليب والعصائر واللحوم وغيرها اصبح منتشراً وشائعاً. تنتج هذه العلب من طبقات من المواد الاتية (73%) من الورق المقوى، (22%) من البلاستك، وللمنتجات التي تحتاج الى تغليف معقم تضاف طبقة رقيقة من الالمنيوم (5%). وأصبح التخلص من الكميات الكبيرة من مخلفات هذه العلب مشكلة كبيرة وخاصة في

المدن الكبيرة والنامية. إيجاد طريقة للاستفادة من مخلفات هذه العلب سيرفع من قيمتها كمخلفات وسيوجد فرص عمل لجمعها وبيعها، بدل ان تكون مبعثرة أو مرمية في سلة المهملات أو على جوانب الطرق وفتحات التصريف.

في هذا البحث اضيفت هذه العلب بعد تقطيعها في الخلطة الاسفلتية ومحاولة معرفة تأثيرها على خواص الخلطة. قطعت العلب بأبعاد (1-6مم) واضيفت لخلطة طبقة رابطة وتم فحص النماذج بطريقة مارشال، وتم تسجيل قيم الثبات والمرونة وحساب العلاقات الحجمية للمختف نب إضافة قطع العلب.

تم الاعتماد على خلطة طبقة رابطة قياسية بنسبة اسفلت (5%) للمقارنة واستخدمت تثبيت هذه النسبة لبقية العينات. استنتج البحث ان استخدام نسبة من العلب المقطعة في الخلطة الاسفلتية بحدود (1-1.5)% سيزيد من ثبات مارشال، كما يسبب زيادة المرونة ونسبة الفجوات الهوائية، ويقلل نسبة الفجوات المملوءة بالاسفلت. نسبة (2)% هناك نقصان في ثبات مارشال، ونقصان في الفجوات الهوائية والفجوات المملوءة بالاسفلت، وزيادة في المرونة. أما لنسبة أكبر من (3)% فالعينة تتفتت وتفشل تحت ضغط جهاز مارشال.

Keywords: Asphalt Pavement, Recycling Materials, Tetra-Pak, HMA, Highway Pavement

INTRODUCTION:

Recycling waste materials is a valuable solution to the expensive and environmentally unacceptable disposal problem for these products. Numerous waste materials result from manufacturing operations, service industries, sewage treatment plants, households and mining. The HMA industry has been pressured in recent years to incorporate a wide variety of waste materials into HMA pavements. This has raised the following legitimate concerns: (a) engineering concerns such as effect on the engineering properties (for example, strength and durability), impact on production, and future recyclability; (b) environmental concerns such as emissions, fumes, odor, leaching, and handling and processing procedures; and (c) economic concerns such as life cycle costs, salvage value, and lack of monetary incentives.

The waste materials can broadly be categorized as follows: (a) Industrial wastes such as cellulose wastes, wood lignin, bottom ash and fly ash; (b) Municipal/domestic wastes such as incinerator residue, scrap rubber, waste glass and roofing shingles; and (c) Mining wastes such as coal mine refuse [Kandhal-1992].

Shingles is one of the types of waste fibers used in HMA. There are two types: organic (paper) and fiberglass. The use of recycled asphalt shingles (RAS) in HMA can provide several advantages, including conservation of landfill space, lower HMA material costs, and improved mix properties [Bartlett-2007].

A study evaluated the properties of stone mastic asphalt mixtures made with paper mill sludge, as well as wastepaper, as fiber additive. Asphalt contents between 5 and 6 percent and sludge or fiber contents between 0.3 and 0.5% resulted in Marshall Specimens with properties generally passing the Department of Public Works and Highways specifications for both medium and heavy traffic road pavement [Mari-2009].

Low density polyethylene is major part of the waste plastic stream. Its use as a recycled additive is HMA concrete pavement extends back to the mid-1970's. The resistance to deformation of HMA concrete modified with approximately (5%) low density polyethylene is significantly better than that of the unmodified mix [Little-1993, Bindu-2010, Justo-2004].

The utilization of fibers in asphalt mixtures is not a new concept; in fact, it has been in use since the early 1900s. The purpose of the fibers was to essentially stabilize the mixture and prevent bleeding of asphalt during hot weather service. Use of fibers in HMA did not come until the late 1950s when the US Army Corps of Engineers, the Asphalt Institute, and the Johns-Manville Co., an asbestos fiber manufacturer, initiated the first evaluation of asbestos fibers in HMA. Results indicated that mixtures containing fibers showed an increase in tensile strength, compressive strength, stability, ability to sustain load after reaching maximum stability, and resistance to weathering [Putman-2011, FORTA-FI-2009, Yoo-2009].

Using shredded Tetra-Pak (TPA) may be desirable for the production of hot mix asphalt (HMA) pavements. It can reduce the waste materials in beneficial way by eliminating the environmental impact of these materials and decrease the disposal budgets required. The properties of the HMA mixture with TPA were evaluated and compared with conventional HMA mixture.

RAW MATERIALS:

To produce packaging materials, TPA uses paperboard (73%), plastic (22%) and -for aseptic packages- aluminum foil (5%). Raw materials production has the greatest environmental impact of all stages within the package life cycle. The plastic (polyethylene) is used in layers on both sides of the paper structure to protect the package from inside and outside moisture. Cartons designed for long life or high acidity content contain aluminum foil, which is about 6-micrometer (0.00024 in) thin. This layer provides additional protection for the content against oxygen, bacteria, undesired flavors and light; **Fig. (1)** Shows TPA packaging components [Abreu-2011, Wikipedia-2012].

TPA introduces a composite of three recycled materials paper (shingle), polyethylene (plastic), and fibers (aluminum foil). This study tried to investigate the change of HMA properties using shredded TPA.

The TPA has been cleaned with water from any substance and dried in oven (60^oC) then hand shredded to (1-6mm) particle size. The shredded TPA used in the mix.

TEST RESULTS AND DISCUSSION:

A binder layer HMA had been used as control mix with (5%) asphalt cement grade (40-50). Five specimens for each of control and shredded TPA with (0.5, 1, 1.5, 2, and 3)% -30specemens in total- prepared and tested with Marshall test method with the same asphalt content. **Table (1)** shows a summary (average) of the test results with the binder layer specifications according to General Specifications for Roads and Bridges, Iraq, (R9-2007).

Figures (2, 3, 4, 5, and 6) show the relationship between the TPA content and the Marshall stability, flow, density, air voids, and voids filled with asphalt (VFB).

The test results show improvement in Marshall stability within (0.5-1.5)% TPA. This may be introduced from the binding effect of plastic and reinforcement effect of fibers which increase the stiffness of the mix. In another hand, Marshall Flow increases due to the sliding effect and lack of interlock of the TPA particles (have smooth faces). For (2%) TPA content the stability start to decrease due to the increase of lack on particle interlock and reach the failure with (3%) TPA content.

Density is decreasing with (0.5-1.5)% TPA content and decreases with (2%). VFB show a decreasing trend. The air voids increased for (0.5-1.5)% TPA content and increases for (2)%. The decrease in density within (0.5-1.5)% range of TPA content may be produces because the orientation of the TPA particles which produce more air voids, in other hand the increase in density with (2%) may be effected by the rearrangement of TPA particles and produce denser mix.

CONCLUSIONS AND RECOMMENDATIONS:

Based on this study of the utilization of shredded TPA in HMA mixtures, the following findings were made:

- The Marshall Stability value of improved within (0.5-1.5)% TPA content, which is higher than the prescribed value of 7 kN for conventional binder layer mix.
- The flow value of mix with (0.5-1.5)% TPA was found to be larger than the range of the prescribed value (2 - 4mm) and increases in trend with TPA content increase.
- Mix density and VFB decreases with the increase of TPA content and air voids increases.

As a conclusion, the mix with TPA may not be used as binder layer according to the procedure taken in this research. On other hand, using TPA within (0.5-1.5)% increase stability which improve the deformation resistance. While increasing in flow and air voids values cause an adverse effect on other properties.

Some recommendations may be taken for future researches including: using controlled shape and finer TPA shredded particles, different mixing techniques and mixing temperatures, experiment with different layer types and different test devices for evaluation other properties.

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Table 1. Marshall Test Results

TPA	Flow	Density	Stability	Air Voids	Voids filled with asphalt (VFB)
%	**mm**	**gm/cm^3**	**kN**	**%**	**%**
Specifications	2 - 4	--	7	3 - 5	70 - 85
0 Control	2.53	2.522	7.25	3.14	82.30
0.5	4.65	2.484	7.32	4.16	80.20
1.0	6.67	2.460	7.47	5.64	78.10
1.5	12.58	2.270	7.70	13.25	72.60
2.0	18.96	2.351	6.39	12.02	67.50

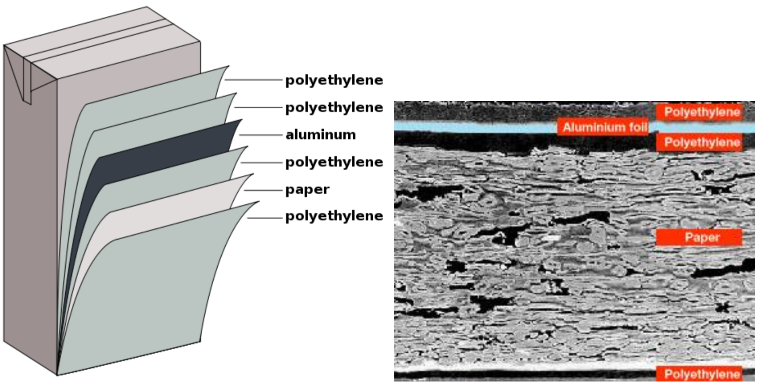

Fig. 1 Tetra-Pak (TBA) Packaging Components with Microscopic Image

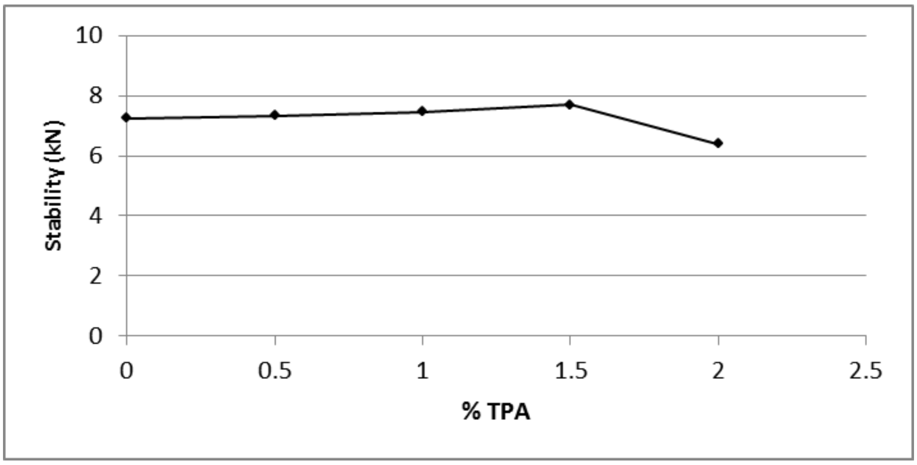

Fig. 2 Shows the Relation between %TPA and Marshall Stability

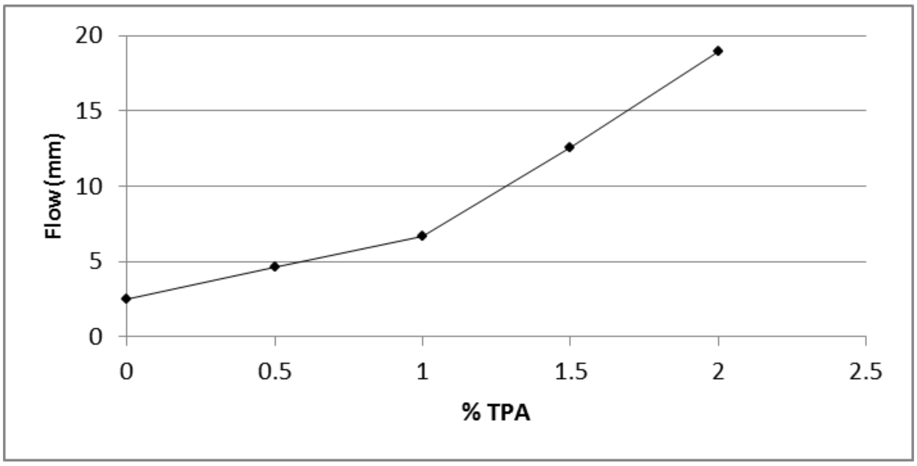

Fig. 3 Shows the Relation between %TPA and Marshall Flow

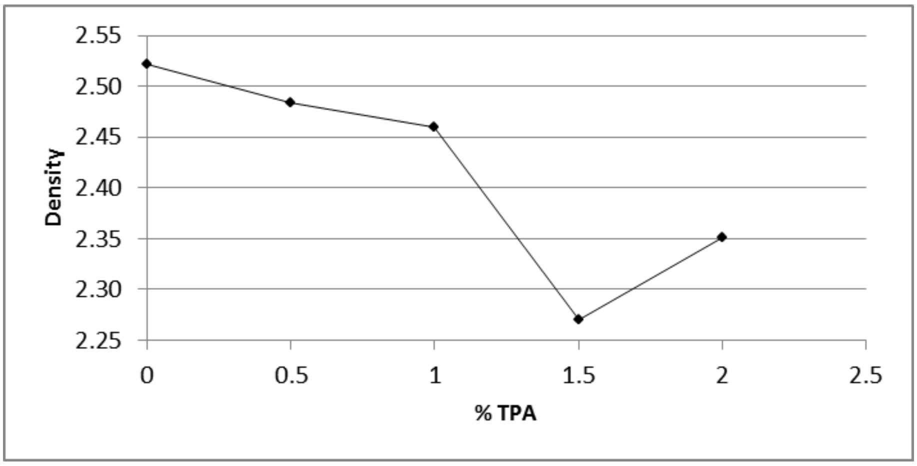

Fig. 4 Shows the Relation between %TPA and Density

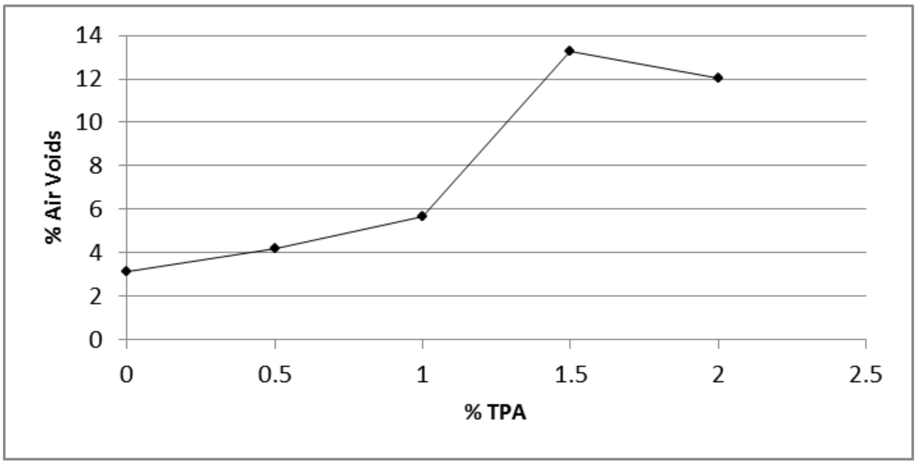

Fig. 5 Shows the Relation between %TPA and % of Air Voids

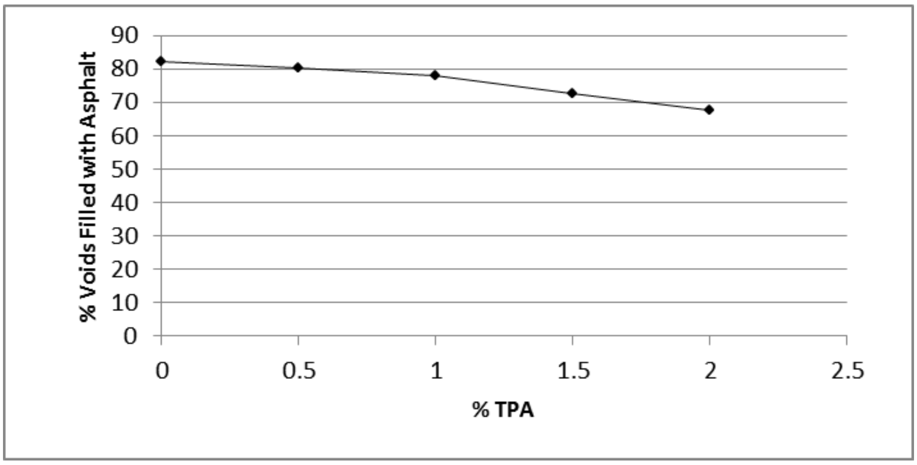

Fig. 2 Shows the Relation between %TPA and % Voids Filled with Asphalt (VFB)