Examination of bituminous mixtures made of conventional aggregates and recycled materials

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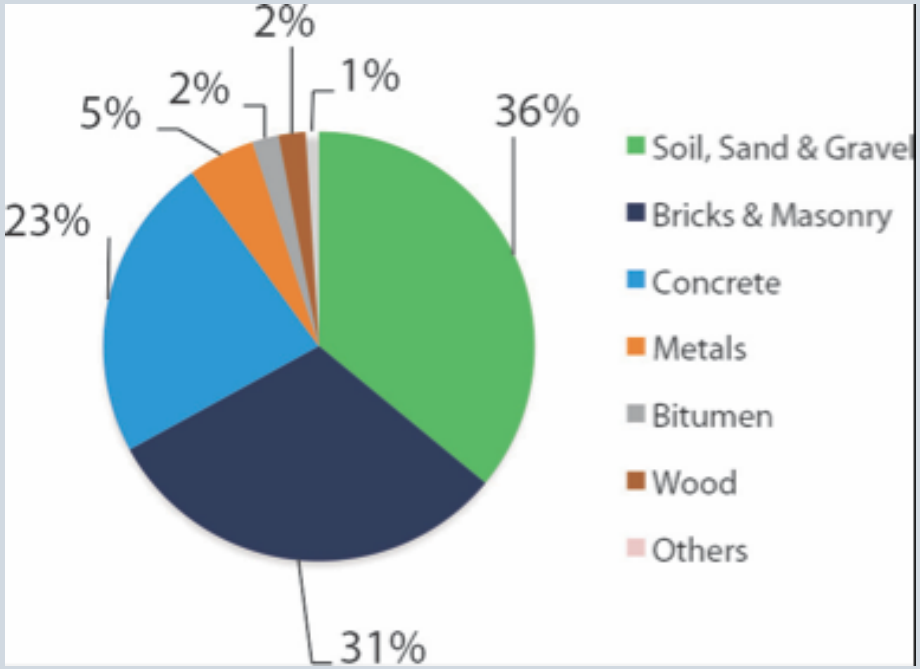
Introduction

Problem

Enormous stream of C&D Wastes are generated annually.

Quantities generated in Europe in 2012 reached the amount of 383millions tones *(Eurostat, 2016),* 50 million tons of which was RAP- Recycled Asphalt Pavement *(Dinis-Almeida M. and Afonso M.L., 2015).*



http://www.cdeglobal.com/uploads/pie-chart.png

Introduction

Legislation

Quantitative targets Joint Ministerial Decision 36259/1757/2010

1/1/2012	1/1/2015	1/1/2020
> 30%	**> 50%**	**> 70%**
Reuse, recycling recovery	Reuse, recycling recovery	Reuse, recycling recovery

Introduction

Solution

- ***We want Sustainable development + reducing extraction of natural resources***
- ***We have C&D Wastes + reduction of quantities of natural resources (aggregates and bitumen)***

SO → many countries through industry are trying to incorporate best practices concerning the use of alternatives in road construction and especially WARM MIX ASPHALT.

Existing know how on Warm Mix Asphalt and RAP

Emissions

Production of hot mix asphalt is responsible for a large consumption due to the heating of its components (aggregates and binder)→ consequent greenhouse gas emissions [*E. Sanchez-Alonso, A. et al, 2011, H. Silva et al, 2010, B. Kheradmand et al, 2013, J. Oliveira et al, 2012, B. Prowell et al, 2011, M.C. Rubio et al, 2012, A. Vaitkus et al, 2009*].

http://insideclimatenews.org/sites/default/files/carbon-emissions.jpg

Worldwide, studies aim at the examination of new technologies which may lead *to* ***reduction in mixing energies*** & ***the emission of*** CO_2, by examining at the same time basic ***properties of the produced mixtures & reduction of the materials quantity doomed to landfills***.

Existing know how on Warm Mix Asphalt and RAP

Emissions

According to test results,

1) Use of recycled aggregates lead to ***a reduction of raw aggregates and 47% reduction in CO_2 during a case study concerning rehabilitation methods in pavements in a major airport in Italy*** (*Magnoni et al, 2016*)***.***

2) Reducing the manufacture temperature of bituminous mixtures leads to lower fuel consumption and cost by 25-35%. At the same time an important ***reduction of greenhouse emissions*** (CO_2 emitted can be reduced between 25 and 40%), as well as in the emissions of CO and NO_x (Carvalho και Barreno, 2013).

Existing know how on Warm Mix Asphalt and RAP

Properties of mixtures

- Warm mix asphalt with RAP, produced at lower mixing temperatures than conventional ones, showed improved stiffness modulus and fatigue resistance. Mixture produced with RAP did not contain any additive to improve the aged bitumen performance [Dinis-Almeida M. and Afonso M.L., (2015)].

- It is possible to manufacture Roller Compacted Concrete (RCC) with a maximum of 50% of RAP materials for road construction *(Settari et al,2015).*

- Utilization of RAP for the production of new one may reach **60%** (Celauro et al, 2010, Dinis-Almeida et al, 2013 , Silva et al, 2012).

- Existing technology allows utilization of ~100% RAP (Ammann-Group,2010).

Experimental part

Materials used/ design of compositions

Materials used for the experimental part of current research were:

- Bitumen 50/70 (Hellenic Petroleum S.A)
- Natural aggregates (sizes 0/16mm originated by the quarry of Lafarge Beton ABEE in Messaio, and quarry of Pavlidis SA in Plagiari Giannitson).
- RAP (originated from road works near the area of Central Macedonia supplied by Anakyklosis Adranon Voreiou Ellados SA) and
- Asphaltite (Selenizza) (supplied by Tsakas Ltd)

The design of bituminous mixtures follows Greek Specifications of bituminous type AC12.5 according to ELOT Technical Specification 1501-05-03-11-04:2009.

AC12.5 is a bituminous mixture of dense/closed type and is used for surface layers due to the finesse of the aggregates used.

Experimental part

TESTING RAW MATERIALS-

RAP

Production of RAP can be made by the use of special equipment, i.e. bitumen cutter. This can be accomplished either by scraping the asphalt layers to the desired thickness, in order to restore it or by the use of an excavator, which removes big particles of pavement (including subbase/base).




- *http://img.directindustry.com/images_di/photo-g/41149-3954987.jpg*
- *http://media.wirtgen-group.com/media/01_wirtgengroup/news_and_press_releases/2014_wirtgen_road_technology_days/W50Ri_01223_HI_961x0.jpg*

RAP
Recycled
Asphalt
Pavement

- RAP is not seen as a waste, but as a material that carries valuable characteristics and that can preserve conventional aggregates for the next generations
- **Reduction in cost** for the production of bituminous mixtures since **less energy** in needed for the **heating of the aggregates** as well as the **reduction in quantities of raw materials needed.**
- Many industries which produce asphalt mixtures are investing on the development of innovative technology achieving production of new bituminous mixtures by the use of 100% of RAP.

Experimental part

Asphaltite

•The bitumen of *Selenizza* ® is contained in an asphaltite ore substance and is extracted from underground galleries or open pit mines at the deposit of Selenice (Albania).

•Under this form, it is called natural bitumen and after a refining process, the obtained clean bitumen is known under the trade name of Selenizza®.

•Asphaltite is used as a modifier of bitumen 50/70, so it is expected to influence bitumen's properties.

Experimental part

Compositions

A/A	Composites	Percentage (%)	Quantity (kg/tn)
1	Bitumen 50/70	4.50	45.00
	Natural aggregates	95.50	955.00
2	Bitumen 50/70	4.50	45.00
	Asphaltite (12% w/t of bitumen 50/70)	0.40	0.13
	Natural aggregates	95.50	955.00
3	Bitumen 50/70	3.30	33.00
	Natural aggregates	67.69	676.90
	RAP (30% w/t of aggregates)	29.01	290.10
4	Bitumen 50/70	3.30	33.00
	Asphaltite (12% w/t of bitumen 50/70)	0.40	0.13
	Natural aggregates	67.69	676.90
	RAP (30% w/t of aggregates)	29.01	290.10

Experimental part

Plant

•The asphalt plant, where all compositions have been produced, is fully licensed and is one of the most modern plants. It is located in the industrial area of Sindos Thessaloniki in zone C, in three contiguous plots, covering a total area of 25.082 m^2.

Supply of aggregates and RAP

Drying oven and installation of sieves and mixer

Silos

Video

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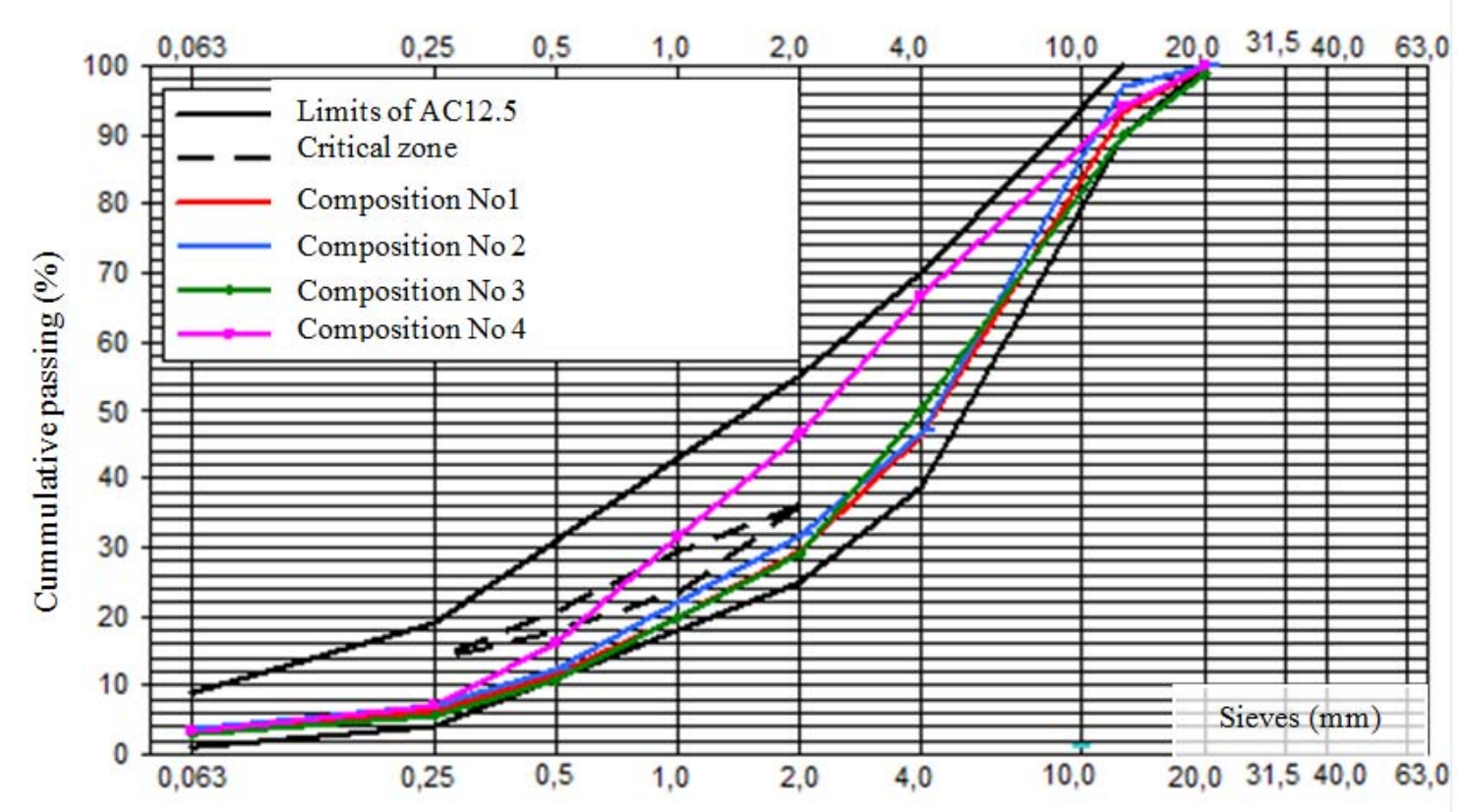
Experimental part

Design of compositions



Experimental part

TESTING RAW MATERIALS-

Asphalt 50/70

A/A	*Test*	*Limits set by EN12591 for bitumen 50/70*	*Result*	*Specification for testing*
1	Penetration at 25°C (0,1mm)	50-70	61	EN1426
2	Softening point (°C)	46-54	49,7	EN1427

Penetration test

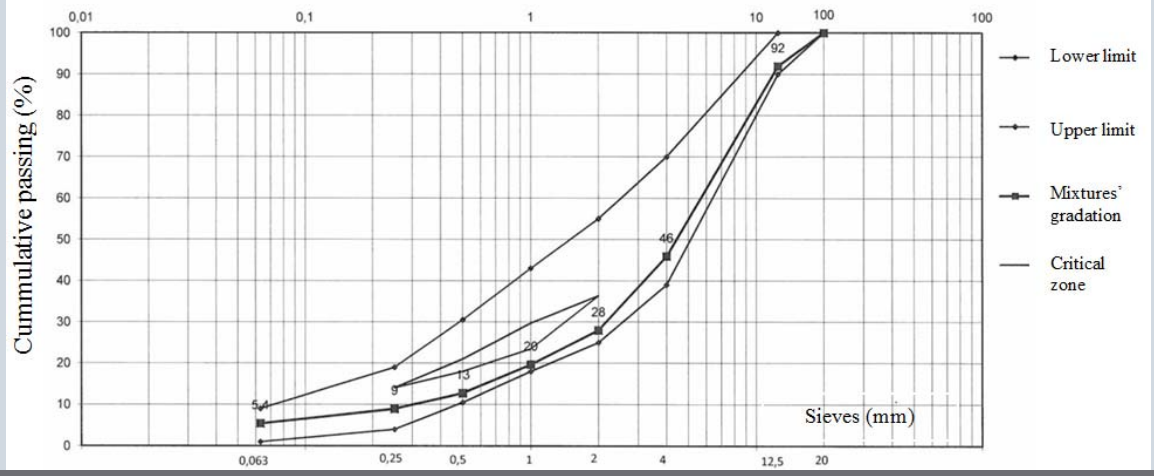
Softening point (Ring & Ball test)

Experimental part

TESTING RAW MATERIALS-

Natural aggregates

A/A	Test	Limits set by ELOT TG 1501-05-03-11-04:2009	Result	Specification for testing
1	Gradation curve	-	See Figure 4	EN933-1
2	Los Angeles test	≤30	26	EN1097-2
3	Water absorption (%) (size 0-4mm/4-8mm/8-16mm)	-	0.13/0.20/0.32	EN1097-6
4	Particle density (Mg/m³) (size 0-4mm/4-8mm/8-16mm)	-	2.69/2.71/2.70	EN1097-6
5	Sand equivalent (%)	≥55	71	EN933-8
6	Methylene blue (gr/kg)	≤10	0.5	EN933-9
7	Flakiness index 4-8mm/8-16mm (FI) (%)	≤25	10/15.9	EN933-3
8	Weathering property-magnesium sulfate test (%) (size 0-4mm/4-8mm/8-16mm)	≤18	2.5/2/2.5	EN1367-2

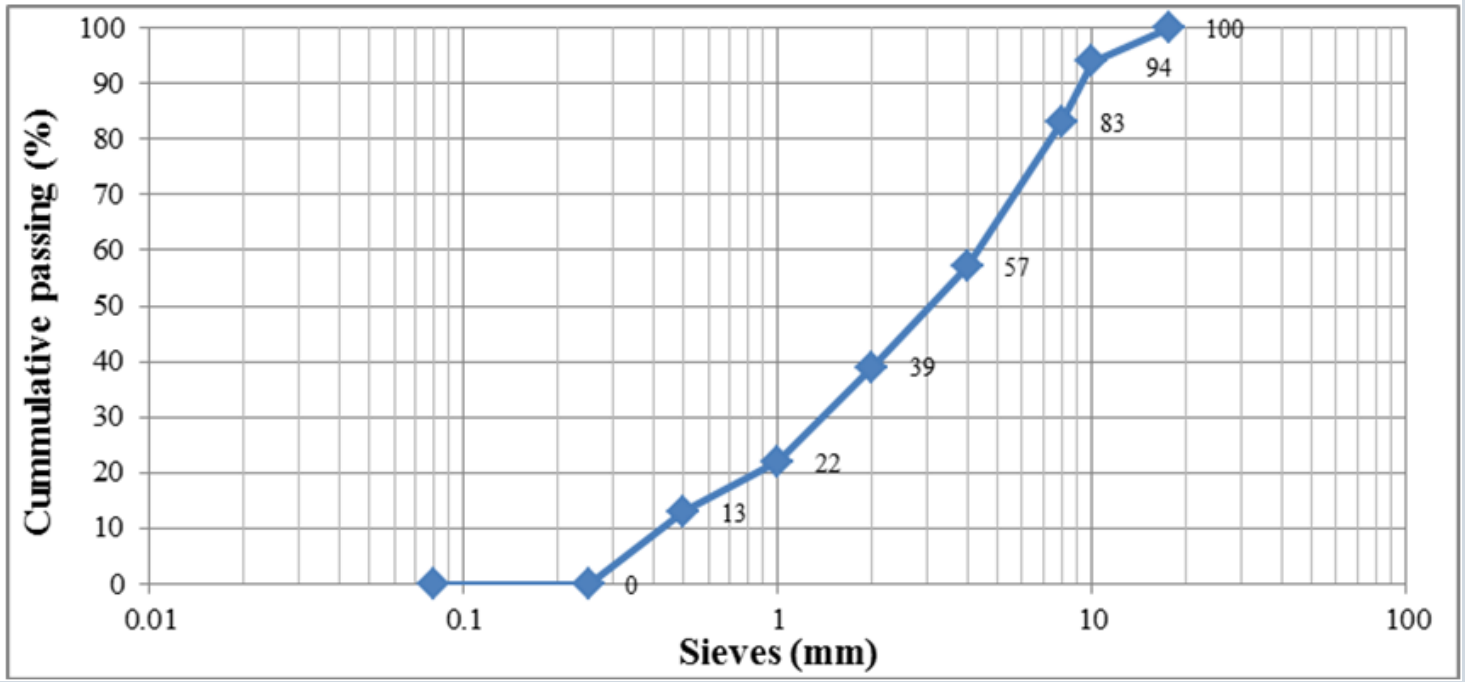


Experimental part

TESTING RAW MATERIALS-

RAP

Water absorption	WA_{24}	1,60%



Experimental part

TESTING RAW MATERIALS-

Asphaltite

A/A	*Test*	*Result*	*Specification*
1	Penetration at 25°C (0,1mm)	0	EN1426
2	Softening point (°C)	120	EN1427
3	Mass loss at 163°C, 5hours (%)	0.08	EN13303

Experimental part

TEST RESULTS-

Marshall characteristics

Selenizza

RAP

Both

	Voids (%)	*VMA (%)*	*VFA (%)*	*Stability (kN)*	*Deformation (mm)*
1	4,10	14,10	70,70	8,5	2,8
2	3,80	14,5	73,80	9,49	2,9
3	4	14,40	72,10	12,81	2,7
4	3,70	13,70	73,40	13,08	2,5

Marshall Characteristics, which have been performed according to EN12697-6/-8/-34

Experimental part

TEST RESULTS-

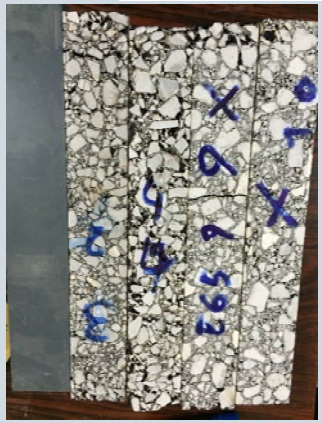
Stiffness

Selenizza

RAP

Both

	Mean height (mm)	*Stiffness MPa*
1	63.1	4133
2	62.9	5205
3	63.6	8981
4	63.6	10249



Testing stiffness @ 20°C of bituminous mixtures (according to EN12697-26)

Experimental part

TEST RESULTS-

Rutting resistance

Selenizza

RAP

Both

	Rate of rutting (μm/ loading cycle)	*Rutting depth (mm)*
1	1.35	3.76
2	1.26	3.45
3	1.38	3.23
4	1.13	3.97

Rutting depth of bituminous mixtures as performed according to EN12697-22

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Experimental part

Total results

Composition	*Stability (percentage of difference %)*	*Deformation (percentage of difference %)*	*Stiffness (percentage of difference %)*	*Rate of rutting (percentage of difference %)*	*Rutting depth (percentage of difference %)*
Bitumen 50/70	*8,5 kN*	*2,8 mm*	*4133 MPa*	*1.35 (μm/ loading cycle)*	*3.76mm*
Bitumen 50/70 + Asphaltite	+12%	+3%	+25,9%	-7%	-8%
Bitumen 50/70 + RAP	+51%	-11%	+117%	+2,5%	-14%
Bitumen 50/70 + Asphaltite+ RAP	+54%	-10%	+148%	-16%	+5,5%

Less irregularities

CONCLUSIONS

Conventional bituminous mixture with bitumen 50/70 satisfies the demands for bituminous layers in places of heavy circulation as set by Greek Specifications ELOT TS 501-05-03-11-04:2009.

Addition of asphaltite at percentage of 12%w/t of bitumen improves not very significant, as expected, mechanical properties of the mixtures.

Addition of RAP at percentage of 30% w/t of the aggregates leads to a significant improvement of the whole list of properties.

Combined use of RAP and asphaltite seems to **improve further** mixtures' properties apart from depth of rut, even though rate of rutting is improved.

CONCLUSIONS

Asphaltite's disadvantages:

- high cost (750€/tn vs~200 €/tn of bitumen 50/70
- operational costs since it is more time consuming as well as its origin, which is found in Albania.

RAP's advantages:

- properties of the mixtures are improved
- cost is decreased since less bitumen and quantity of natural resources are used for the production of the final mixture and
- waste is exploited and
- natural resources are saved for next generations.

CONCLUSIONS

RECYCLING IS CIVIL ENGINEER'S FUTURE!!!

Unfortunately, Greek legislation allows at the moment the use of RAP at percentage up to

- 10%w/t of the aggregates for surface bituminous layers and
- 20% for lower layers.

Entering of higher percentages of RAP in Greek legislation and combined use of RAP and RA (Recycled Aggregates) for even higher environmental benefit will be examined further.

Even a slight increase of percentage of RAP used in bituminous mixtures is beneficial and can also lead to the achievement of goals as are set by the Greek legislation (GMD36259/1757/E103/24-08-2010) which demands the reuse and recycling of 70% of C&D Wastes by 2020.

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Thank you for your attention

Questions??