CEDR Transnational Road Research Programme
Call 2012: Recycling: Road construction in a post-fossil fuel society

funded by Denmark, Finland, Germany,
Ireland, Netherlands and Norway

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

AllBack2Pave

Towards a sustainable 100% recycling of reclaimed asphalt in road pavements

- End User's Manual -

International Workshop on Recycling:
Road Construction in a post-fossil fuel Society

TECHNISCHE UNIVERSITÄT DRESDEN

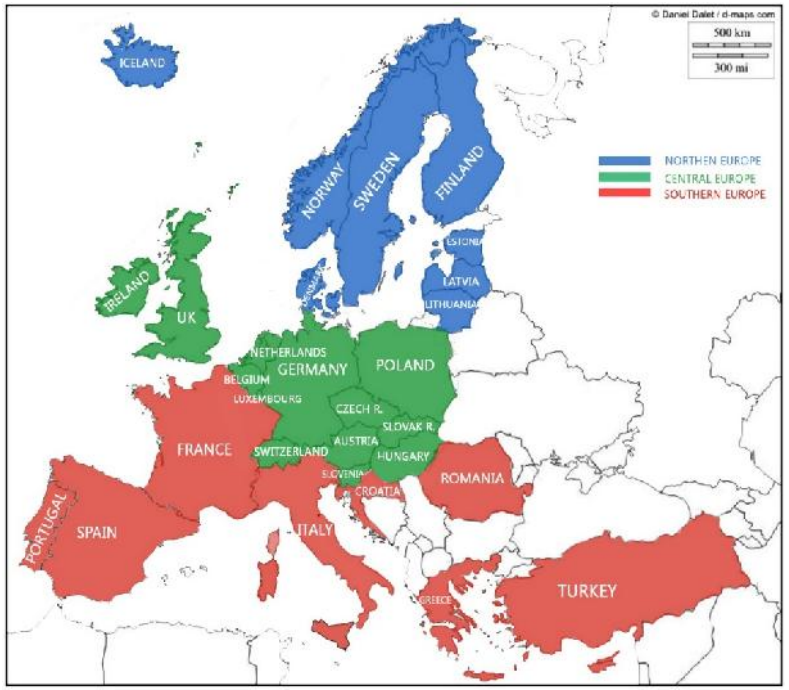
The University of Nottingham

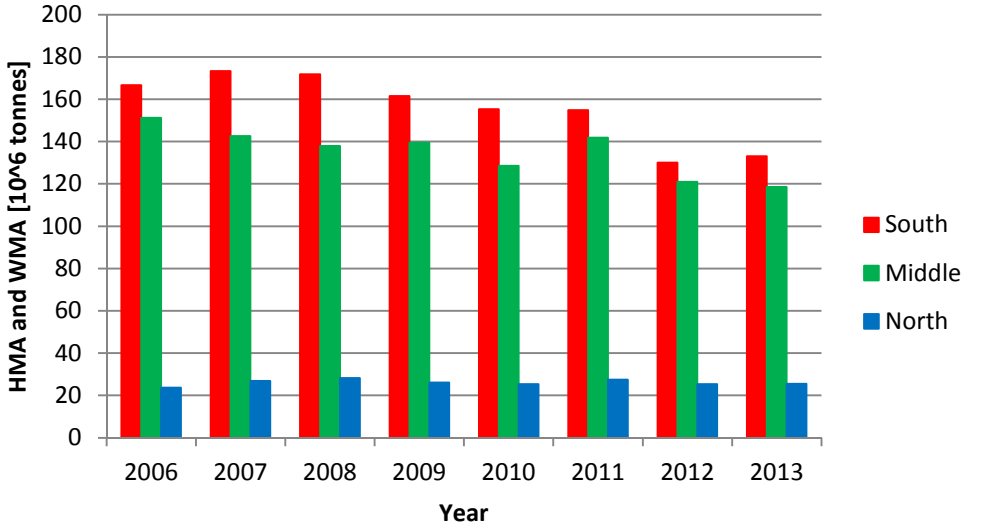
UNIVERSITÀ DEGLI STUDI DI PALERMO

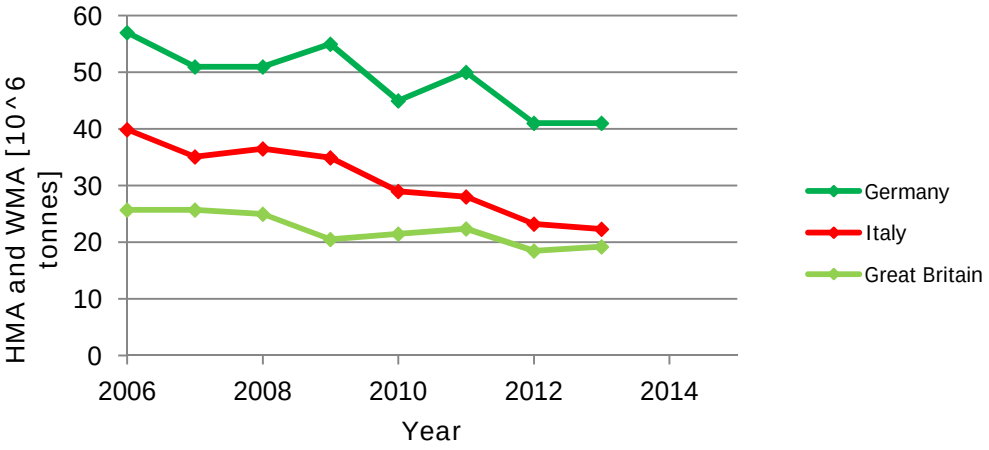
Outline

- Introduction
- Scope and Objectives
- Methodology
- Case Study
- Conclusions

Introduction







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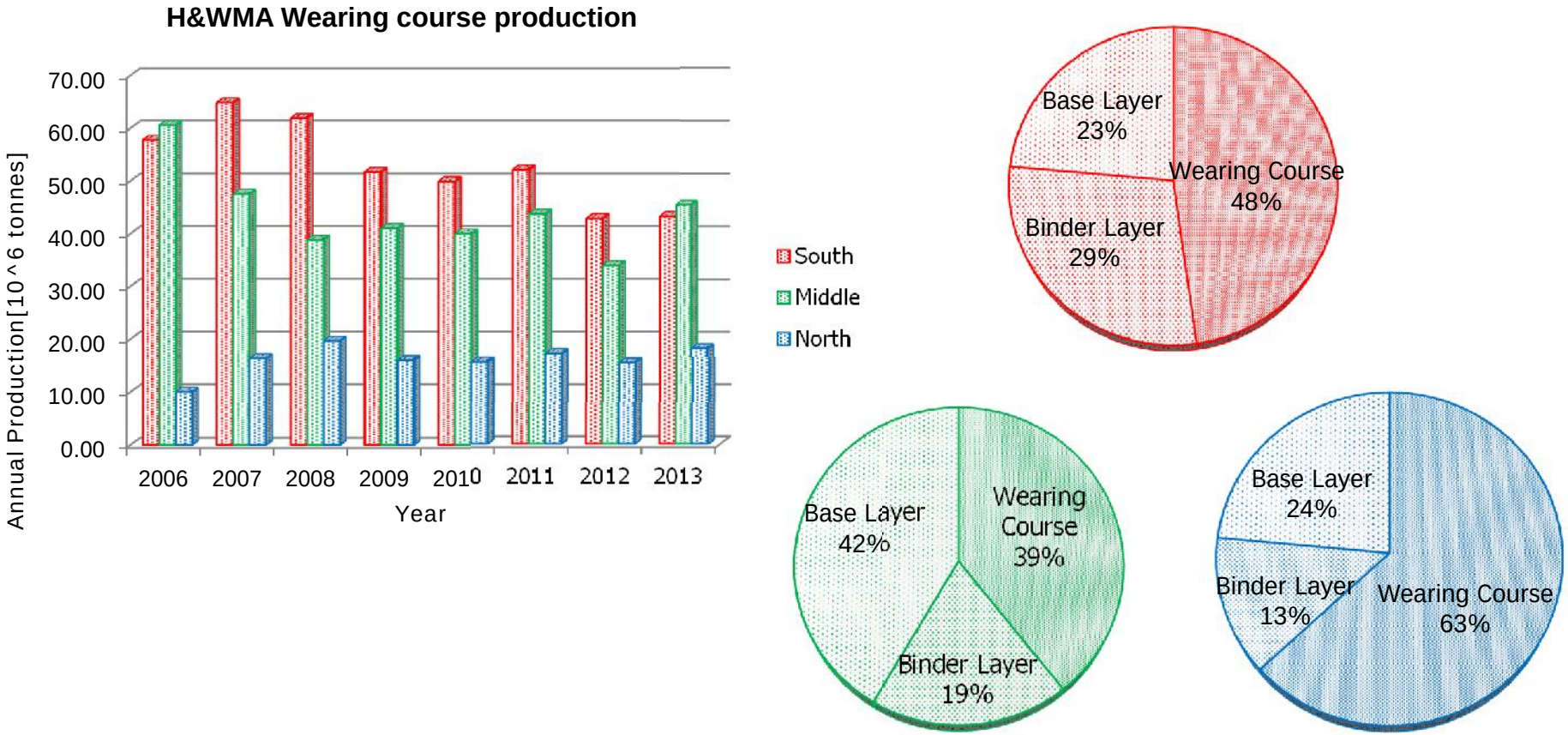

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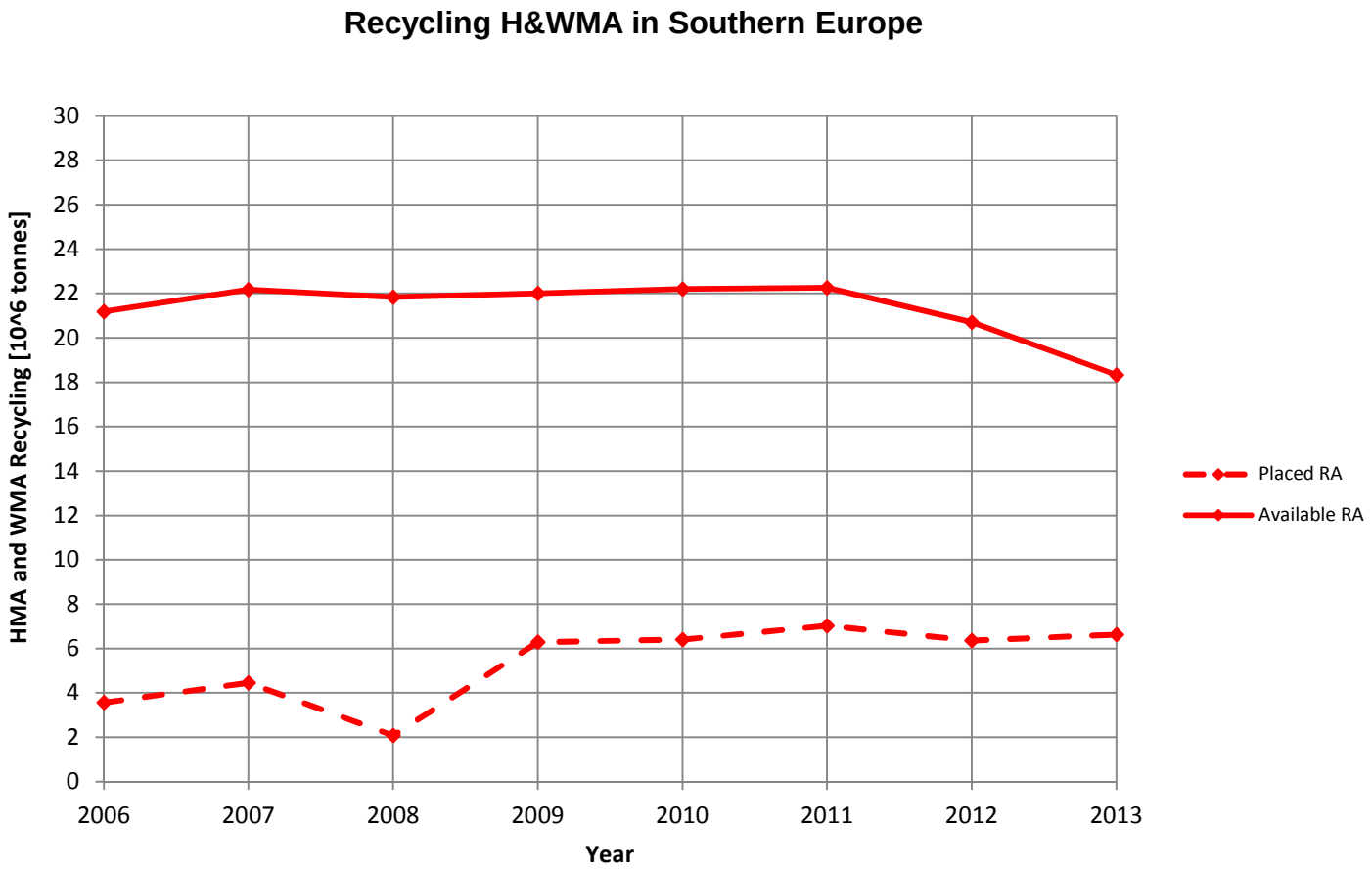
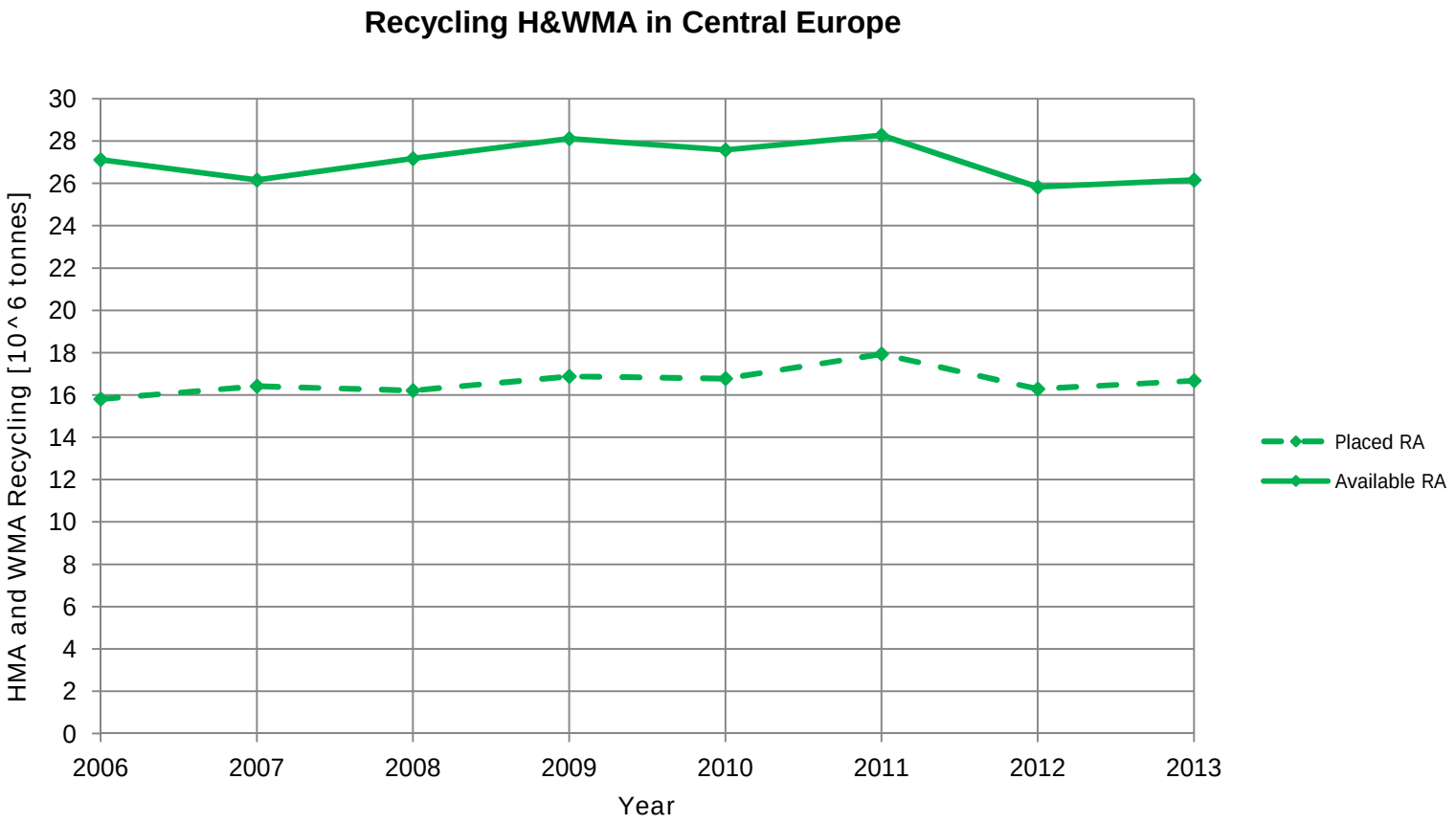
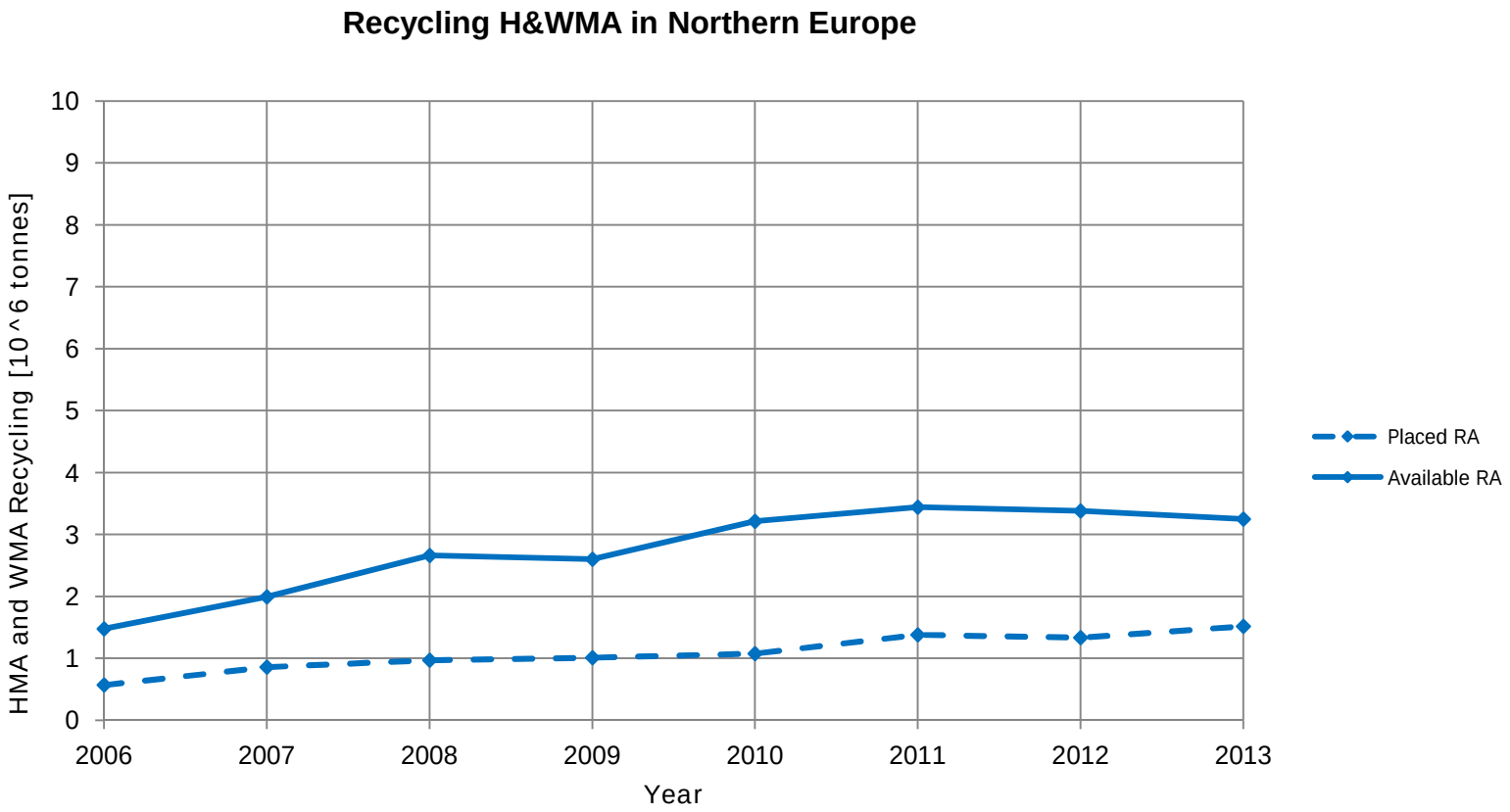


Introduction



Introduction



Introduction

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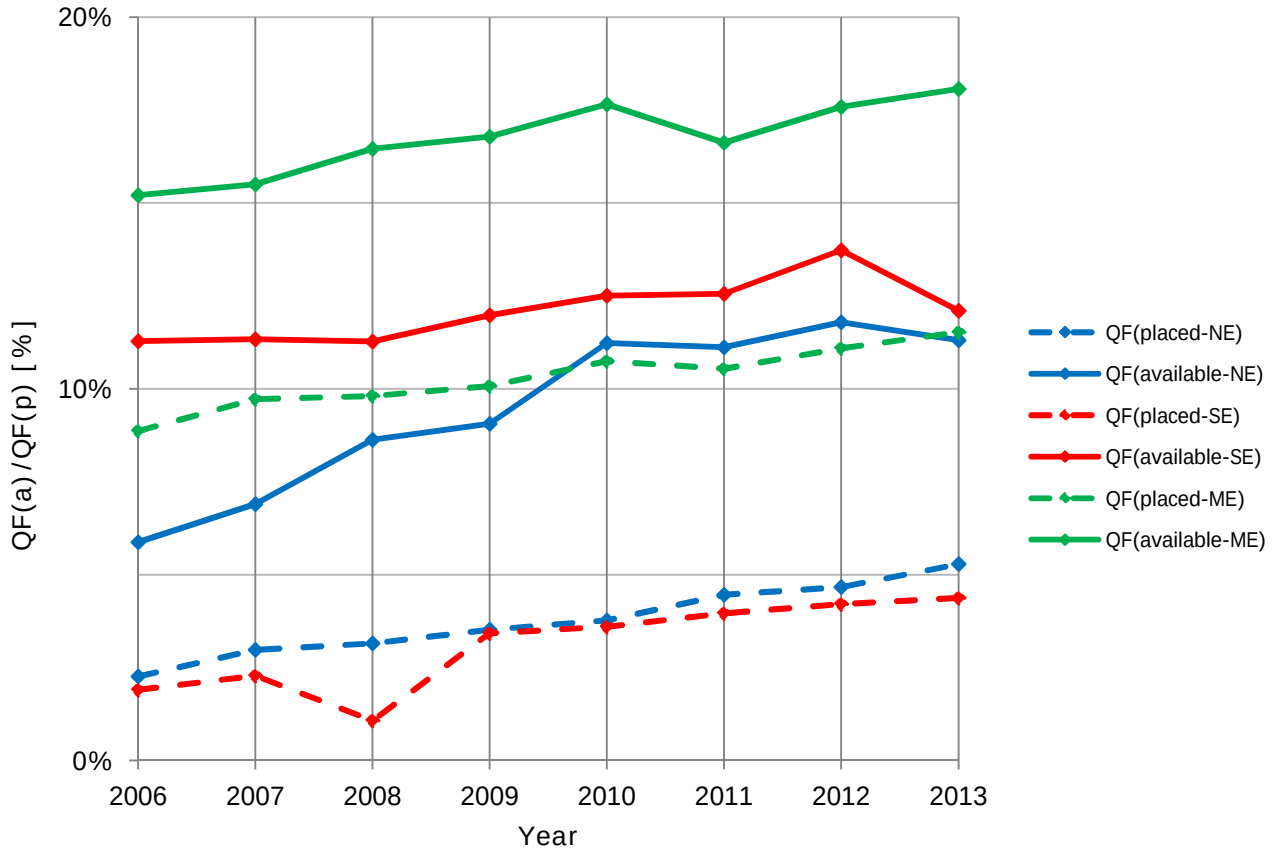


Introduction

AllBack2Pave

KEY CONSIDERATIONS

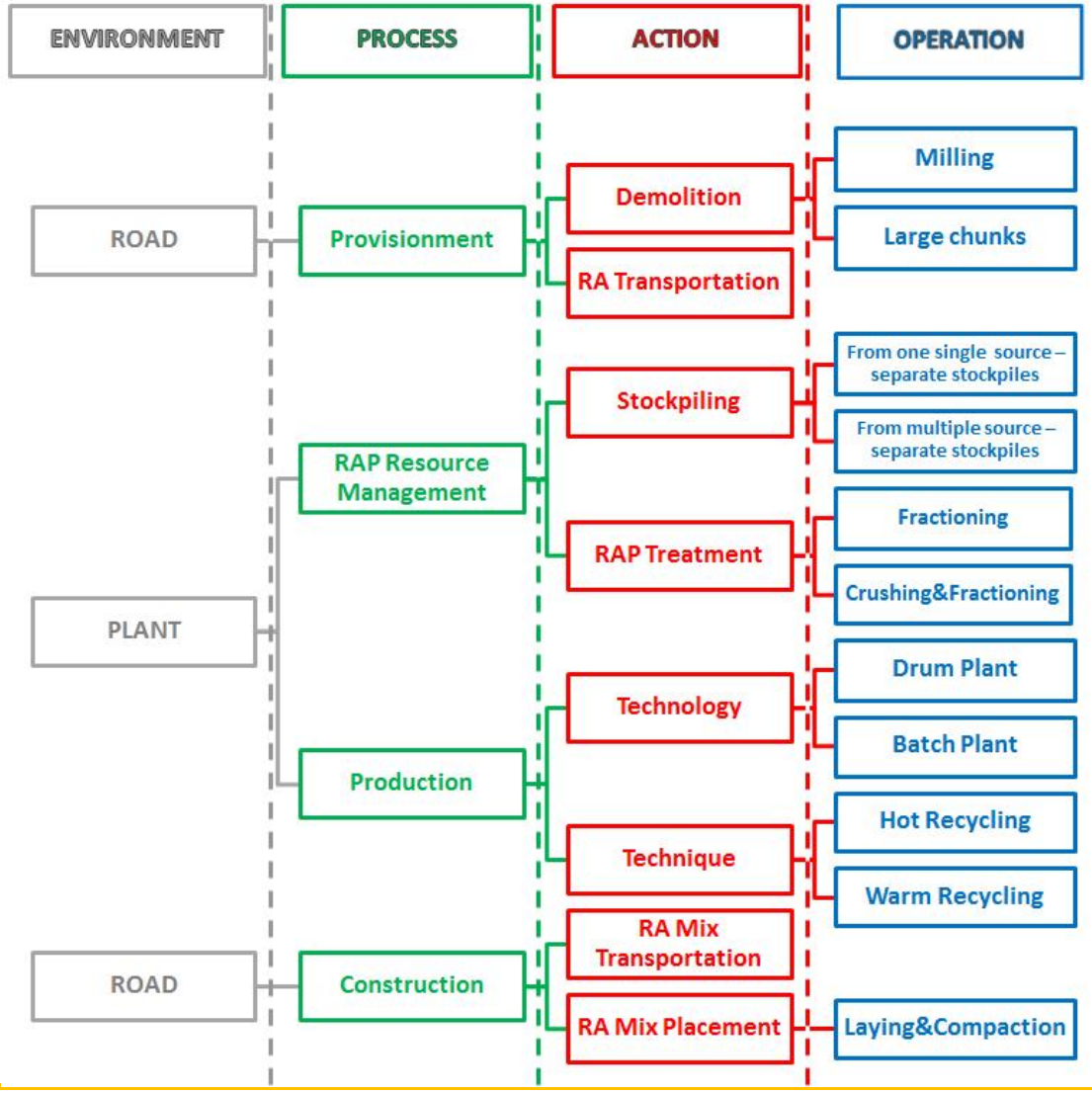
- **European production of H&WMA is substantially decreasing within the continent area and globally;**
- **RA production in Europe shows a marked growth until 2011 and after it there is a significant decrease;**
- **RA used within flexible pavements shows a fluctuating tendency still growing.**

Scope and Objectives

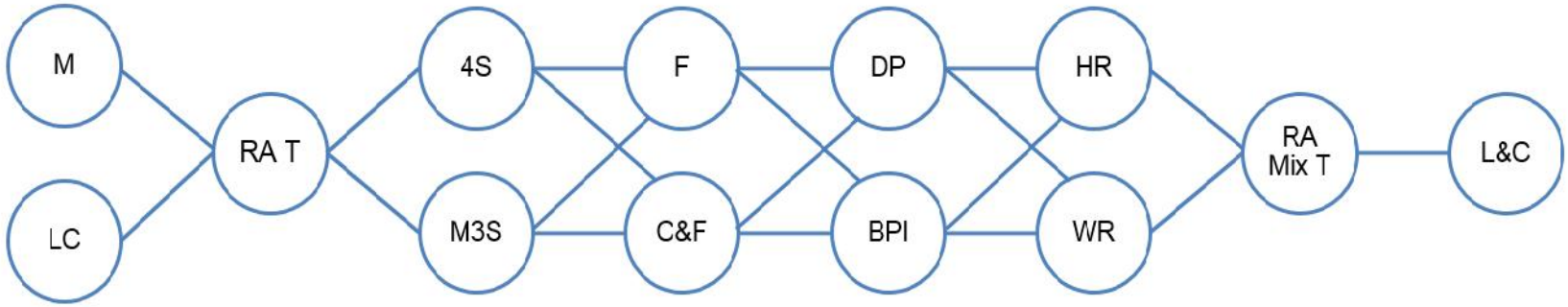
The scope is to define the guidelines of drafting of an RA end−users manual ad−dressed to all stakeholders involved such as road agencies, production plants and construction enterprises.

Two technical goals should be reached: the consensus between mixtures of laboratory and mixtures produced in the plant; the achievement of the pavement performances provided by design.

Scope and Objectives



Methodology



M = Milling
LC = Large Chunks
RA T = RA Transportation
4S = Single Source – Separate Stockpile
M3S = Multiple Source – Separate Stockpile
F = Fractioning
C&F = Crushing and Fractioning

DP = Drum Plant
BPI = Batch Plant
HP = Hot Recycling
WP = Warm Recycling
RA Mix T = RA Mix Transportation
L&C = Laying and Compaction

Methodology

USER/OPERATION MATRIX			
USER / OPERATION	ROAD AGENCY	PLANT COMPANY	CONSTRUCTION ENTERPRISE
Milling	•		•
Large Chunks	•		
RA Transportation			•
Single Source – Separate Stockpile	•	•	
Multiple Source – Separate Stockpile	•	•	
Fractioning		•	
Fractioning & Crushing		•	
Drum Plant		•	
Batch Plant		•	
Hot Recycling		•	
Warm Recycling		•	
RA Mix Transportation	•		•
Laying & Compaction	•		•

Methodology

OVERALL CHECK LIST ROAD AGENCY				
OPERATION	BASIC RULE (CODE)	TYPE OF RULE	DESCRIPTION	DONE (YES/NOT)
Milling	Selection the milling depth (M-SMD1)	BP	Based on examination of pavement cores. Frequency of the cores is 1set/km×lane on highway; 1set/block×lane on street. One set is composed by 3 cores along cross section at least	
Milling	Check the Operations led by the Enterprise (M-COE1)	S	Verifying the required milling depth	
Milling	Check the Operations led by the Enterprise (M-COE2)	S	Verifying the required pavement area to be dismantled	
Large Chunks	Selection the Thickness of Pavement to be dismantled (LC-STP1)	BP	Based on examination of pavement cores. Frequency of the cores is 1set/km×lane on highway; 1set/block×lane on street. One set is composed by 3 cores along cross section at least	
Large Chunks	Check the Operations led by the Enterprise (LC-COE1)	S	Verifying the required milling depth	
Large Chunks	Check the Operations led by the Enterprise (LC-COE2)	S	Verifying the required pavement area to be dismantled	
Single Source Separate Stockpiles	making RAP Quality Control Plan (4S-QCP1)	BP	Determining the RAP gradation by regular test (for replenishing stockpiles). Frequency is one test/1tons at least	
Single Source Separate Stockpiles	making RAP Quality Control Plan (4S-QCP2)	BP	Determining the RAP binder content by regular test (for replenishing stockpiles). Frequency is one test/1tons at least	
Single Source Separate Stockpiles	making RAP Quality Control Plan (4S-QCP3)	BP	Determining the RAP bulk specific gravity by regular test (for replenishing stockpiles). Frequency is one test/1tons at least	
Multiple Source Separate Stockpiles	making RAP Quality Control Plan (M3S-QCP1)	BP	Determining the RAP gradation by regular test (for replenishing stockpiles). Frequency is three test/1tons at least	
Multiple Source Separate Stockpiles	making RAP Quality Control Plan (M3S-QCP2)	BP	Determining the RAP binder content by regular test (for replenishing stockpiles). Frequency is three test/1tons at least	
Multiple Source Separate Stockpiles	making RAP Quality Control Plan (M3S-QCP3)	BP	Determining the RAP bulk specific gravity by regular test (for replenishing stockpiles). Frequency is three test/1tons at least	
RA Mix Transportation	Checking Transportation Time (RAMT-CHTT1)	BP	Measuring the time between plant and site (in average maximum 90mins)	
Laying & Compaction	Testing RAP Quality of the Laying and Compaction (LC-TQ1)	S	Probing of the pavement and testing on the cores. Frequency of the cores is 1set/km×lane on highway at least; 1set/block×lane on street at least. One set is composed by 3 cores along cross section at least	

Methodology

OVERALL CHECK LIST PLANT COMPANY				
OPERATION	BASIC RULE (CODE)	TYPE OF RULE	DESCRIPTION	DONE (YES/NOT)
Single Source Separate Stockpiles	Storage Area (4S-SA1)	BP	Minimum area should be not less than 1500m^2. Area should be sloped (six degree is ideal)	
Single Source Separate Stockpiles	Storage Area (4S-SA2)	BP	Treatment of the surface area (no water, no clay)	
Single Source Separate Stockpiles	Storage Area (4S-SA3)	BP	Permeable to air roof with permeable to air membrane	
Single Source Separate Stockpiles	Stockpiling (4S-S1)	BP	Stockpile must have conical shape with maximum height of 6 m	
Single Source Separate Stockpiles	Stockpiling (4S-S2)	R	Searching for deleterious materials (EN 12697-42) Sampling according to EN 932-1	
Single Source Separate Stockpiles	Stockpiling (4S-S3)	R	Determining aggregate grading (EN-13043) Sampling according to EN 932-1	
Single Source Separate Stockpiles	Stockpiling (4S-S4)	R	Determining binder content (EN 12697-1) Sampling according to EN 932-1	
Multiple Source Separate Stockpiles	Storage Area (M3S-SA1)	BP	Minimum area should be not less than 1500m^2. Area should be sloped (six degree is ideal)	
Multiple Source Separate Stockpiles	Storage Area (M3S-SA2)	BP	Treatment of the surface area (no water, no clay)	
Multiple Source Separate Stockpiles	Storage Area (M3S-SA3)	BP	Permeable to air roof with permeable to air membrane	
Multiple Source Separate Stockpiles	Stockpiling (M3S-S1)	BP	Stockpile must have conical shape with maximum height of 6 m	
Multiple Source Separate Stockpiles	Stockpiling (M3S-S2)	R	Searching for deleterious materials (EN 12697-42). Sampling according to EN 932-1. Number of samples equal to 1.5 of number of samples according to EN 12697-42 and EN 932-1	
Multiple Source Separate Stockpiles	Stockpiling (M3S-S3)	R	Determining aggregate grading (EN-13043). Sampling according to EN 932-1. Number of samples equal to 1.5 of number of samples according to EN 13043 and EN 932-1	
Multiple Source Separate Stockpiles	Stockpiling (M3S-S4)	R	Determining binder content (EN 12697-1). Sampling according to EN 932-1. Number of samples equal to 1.5 of number of samples according to EN 12697-1 and EN 932-1	

Methodology

OVERALL CHECK LIST PLANT COMPANY				
OPERATION	BASIC RULE (CODE)	TYPE OF RULE	DESCRIPTION	DONE (YES/NOT)
Fractioning	Number of Screening (Sieves) Unit (F-NSU1)	BP	The Plant must have 3 screening unit at least, typically 3/4, 3/8, 3/16 (ASTM series or equivalent)	
Crushing & Fractioning	Preliminary Screening (CF-PS1)	BP	Preliminary screening of the finer particles by a suitable sieve (3/16 ASTM series or equivalent)	
Crushing & Fractioning	Before & After analysis of RAP gradation (CF-BAG1)	BP	Gradation control before & after the in line crusher to determine the RAP aggregate size (within 1B&A analysis 2 samples for RAP source)	
Crushing & Fractioning	Number of Screening (Sieves) Unit (CF-NSU1)	BP	The Plant must have 3 screening unit at least, typically 3/4, 3/8, 3/16 (ASTM series or equivalent)	
Drum Plant	Mixing RAP (DP-MRAP1)	BP	The plant must have split feed drum mixer	
Drum Plant	Mixing RAP (DP-M2)	BP	The plant must have double barrel drum mixer	
Drum Plant	Mixing RAP (DP-M3)	BP	The plant must have counterflow drum mixer	
Batch Plant	Drying RAP (BP-D1)	BP	The plant must have a tandem rotary drum dryer (T=110÷130°C)	
Batch Plant	Drying RAP (BP-D2)	BP	The plant must have a rotary drum dryer with recycling ring (T=110÷130°C)	
Hot Recycling	Heating Temperature Control (HR-HTC1)	BP	Verifying the heating temperature of RA is within the range 110÷130°C	
Hot Recycling	Mixing Time Control (HR -MTC1)	BP	Verifying the mixing time is within the range 25÷90 s	
Hot Recycling	Emission Control (HR-EC1)	R	Verifying the pollutant emission according to UE Directive 75/2010	
Warm Recycling	Heating Temperature Control (WR-HTC1)	BP	Verifying the heating temperature of RA is within the range 110÷130°C	
Warm Recycling	Mixing Time Control (WR-MTC1)	BP	Verifying the mixing time is within the range 25÷90 s	
Warm Recycling	Emission Control (WR-EC1)	R	Verifying the pollutant emission according to UE Directive 75/2010	
Warm Recycling	Addition Systems for Plant (WR-ASP1)	BP	In the case of use of foam bitumen as additive it's needed to implement with a foaming unit or extra silos	

Methodology

OVERALL CHECK LIST CONSTRUCTION ENTERPRISE				
OPERATION	BASIC RULE (CODE)	TYPE OF RULE	DESCRIPTION	DONE (YES/NOT)
Milling	Control Fine Content (M-CFC1)	BP	Minimizing fines content (slow forward speed or fast drum rotation will generate more undesirable fines)	
Milling	Contamination Control (M-CC1)	BP	Making sure the milled material is not contaminated with soil, base material, paving geotextiles, or other debris (maximum 1%)	
RA Transportation	Truck Maintenance (RAT-TM1)	BP	Cleaning the truck beds before hauling millings or useable RA	
RA Transportation	RA Dumping (RAT-D1)	BP	Clearly instructed where to dump loads	
RA Mix Transportation	Truck Selection (RAMT-TS1)	BP	Selecting weight, size and type of the trucks to match the conditions on site	
RA Mix Transportation	Truck Maintenance (RAMT-TM1)	BP	Cleaning the truck bed with suitable agents. (Use of oils, e.g. diesel oil is strictly prohibited)	
RA Mix Transportation	Loading Control (RAMT-LC1)	BP	During loading visually verifying defects (e.g. segregation, wrong temperature, fatting-up or dry mixes)	
RA Mix Transportation	Truck Equipment (RAMT-TE1)	BP	Equipping all vehicles with windproof tarpaulins	
Laying & Compaction	Testing RAP Quality of the Laying and Compaction (LC-TQ2)	S	Measuring the temperature at the beginning of the laying (in minimum average value 140°C for HMA; in minimum average value 110°C for WMA)	
Laying & Compaction	Environmental Condition Checking (LC-ECC1)	BP	For WMA no laying and compacting if wind speed is more than 10 km/h and temperature is last than 10°C	
Laying & Compaction	WMA Compaction (LC-WMAC1)	BP	For WMA reducing the effort compaction (number of passage and/or loading wheel) compared to HMA	

Methodology

Numerical Criterion for Basic Rule

TYPE OF RULE	R	S	BP
WEIGHT VALUE (WV)	3	2	1

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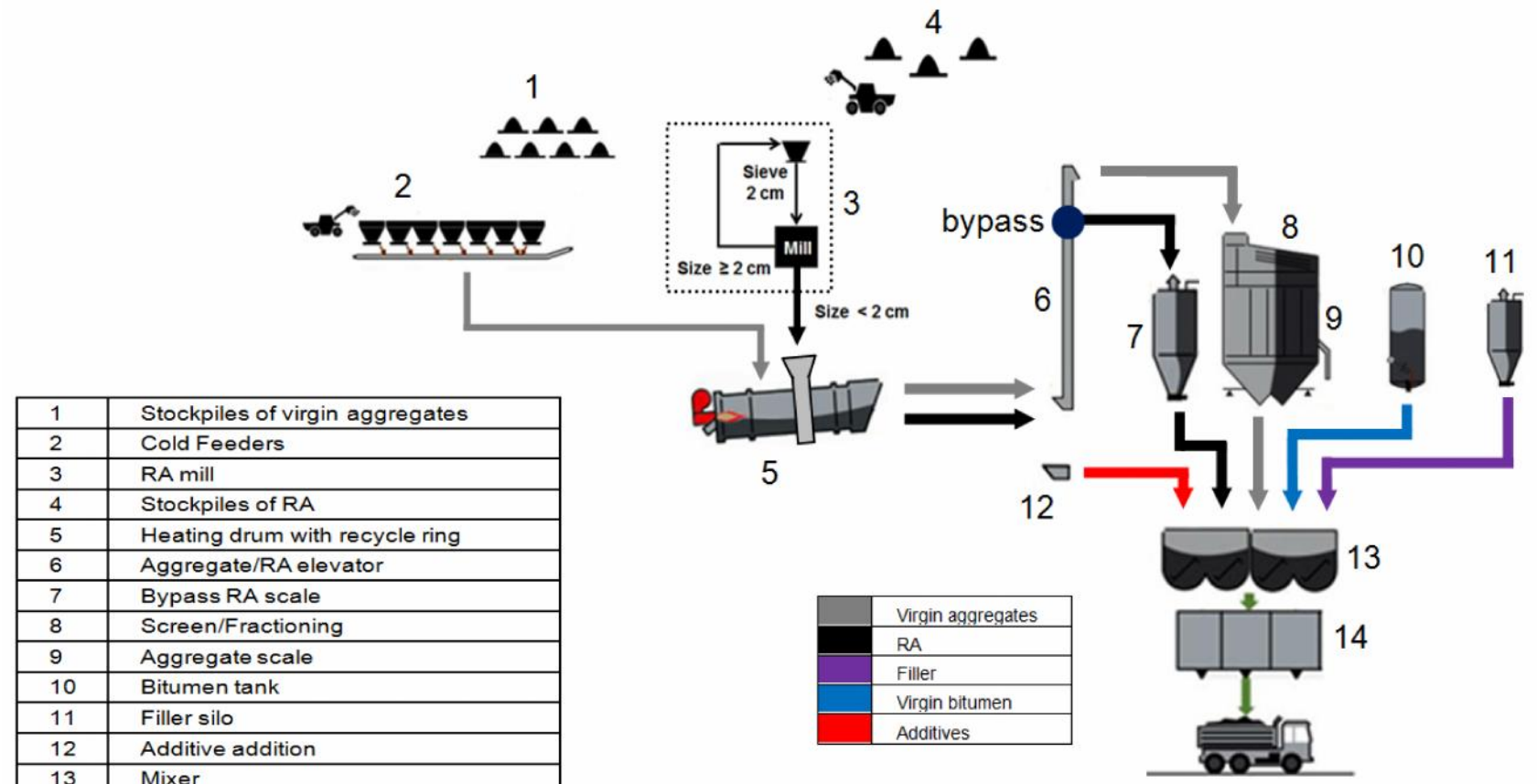
CHECK LIST RA PROCESS - PATH 1												
USERS ACTIVITIES: REGULATIONS SPECIFICATIONS AND BEST PRACTICES												
OPERATION	ROAD AGENCY				PLANT COMPANY				CONSTRUCTION ENTERPRISE			
	BASIC RULE (CODE)	TYPE OF RULE	DONE (YES/NOT)	WEIGHT VALUE	BASIC RULE (CODE)	TYPE OF RULE	DONE (YES/NOT)	WEIGHT VALUE	BASIC RULE (CODE)	TYPE OF RULE	DONE (YES/NOT)	WEIGHT VALUE
Milling	M-SMD1	BP		Weight/0					M-CFC1	BP		Weight/0
	M-COE1	S		Weight/0					M-CC1	BP		Weight/0
	M-COE2	S		Weight/0								
RA Transportation									RAT-TM1	BP		Weight/0
									RAT-D1	BP		Weight/0
From one single source - separate stockpiles	4S-QCP1	BP		Weight/0	4S-SA1	BP		Weight/0				
	4S-QCP2	BP		Weight/0	4S-SA2	BP		Weight/0				
	4S-QCP3	BP		Weight/0	4S-SA3	BP		Weight/0				
					4S-S1	BP		Weight/0				
					4S-S2	R		Weight/0				
					4S-S3	R		Weight/0				
					4S-S4	R		Weight/0				
Fractioning					F-NSU1	BP		Weight/0				
Batch Plant					BP-D1	BP		Weight/0				
					BP-D2	BP		Weight/0				
Hot Recycling					HR-HTC1	BP		Weight/0				
					HR-MTC1	BP		Weight/0				
					HR-EC1	R		Weight/0				
RA Mix Transportation	RAMT-CHTT1	BP		Weight/0					RAMT-TS1	BP		Weight/0
									RAMT-TM1	BP		Weight/0
									RAMT-LC1	BP		Weight/0
									RAMT-TE1	BP		Weight/0
Laying& Compaction	LC-TQ1	BP		Weight/0					LC-TQ2	S		Weight/0
									LC-ECC1	BP		Weight/0
									LC-WMAC1	BP		Weight/0

Case Study

AllBack2Pave

Operation Diagram of the Italian mixing plant



1	Stockpiles of virgin aggregates
2	Cold Feeders
3	RA mill
4	Stockpiles of RA
5	Heating drum with recycle ring
6	Aggregate/RA elevator
7	Bypass RA scale
8	Screen/Fractioning
9	Aggregate scale
10	Bitumen tank
11	Filler silo
12	Additive addition
13	Mixer
14	Hot mix storage silo

Case Study

- **Four asphalt mixes for wearing course were manufactured in mixing plant 0% RA, 30% RA + Add, 60% RA + Add and 90% RA + Add respectively according to the laboratory design by SUPERPAVE method (level 1)**
- **The full-scale production was carried out by the main mixing plant of Ferrara Accardi & F. s.r.l. that is located in Catania (Sicily). This mixing plant is the largest one in Sicily for annual production of conventional asphalt, besides being one of the few mixing plants equipped with technology for the production of reclaimed asphalt**
- **The plant is found to have a maximum amount of 200 ton/h; it is of the discontinuous type with drum mixer with ring recycling**
- **Reclaimed Asphalt comes from only one source**
- **The storage area of the RA is of about 2000 m2; in particular the base underneath the piles is made of reinforced concrete and kept free from pollutant and water runoff.**
- **The piles are not protected from the elements and have substantially conical shape with heights of over 5**

Case Study

- **The production was carried out on December 4th and 5th 2014.The final amount of each asphalt mix was of about 3 tons**
- **The mixing temperature was checked during the taking of asphalt from the silo.**
- **It should be noted that the production was carried out on a day of normal operation of the plant; therefore the manufacturing of the four mixtures was at alternating commercial productions, which, on that day, did not include mixtures with reclaimed asphalt**
- **The mixtures with RA were carried out with the addition of warm-mix additive; this has allowed to maintain the mixing temperature on ordinary values even for the mixtures with the highest RA percentage**

Mix	Mixing temperature target [°C]
0% RA	160
30% RA +Add	163
60& RA + Add	165
90% RA + Add	170

Case Study

- As regards the mixture with 60% of RA, in order to abide by the temperature limit of 200° C the production was carried out by putting in the ring of recycling only 50% of the total weight of RA, while the remaining cold part was directly sent to the mixer, once the virgin aggregate and hot RA were already put inside

- Since approximately 300 kg per ton of the mixture were added to the ambient temperature of 15° C, in order to obtain the expected mixing temperature, it was necessary to carry out an increase of heating temperatures of virgin aggregates and the RA; to this end two productions have been carried out: in the first case a final mixing temperature of 158° C was achieved; in the second case, the excessive heating of the materials coming from the drum provoked a final mixing temperature of 200° C

- For the purposes of the research it was considered just the mixture produced at lower temperature

Case Study

- As regards the mixture with 90% of RA, because of the limits of the system, it could not to reach a mixing temperature above 110° C
- Two attempts were made to mixing, considering two different percentages of RA cold (50% and 33% with respect to the overall quantity of RA); however, the too small amount of virgin aggregate inside the drum (approximately 100 kg per ton of mixture) did not allow a sufficient heat exchange to ensure the attainment of temperatures necessary for the blending. In addition, the shortage of virgin material within the drum did increased the temperature of the fumes, leading it abruptly to the threshold value permitted by the system and forcing, consequently, the operator to decrease the energy of the burner of the drum.
- Thus all mixes were produced except the one with 90% of RA. The latter was then manufactured in the laboratory for the experimental survey.

Case Study

AllBack2Pave

OVERALL CHECK LIST PLANT COMPANY				
OPERATION	BASIC RULE (CODE)	TYPE OF RULE	DESCRIPTION	DONE (YES/NOT)
Single Source Separate Stockpiles	Storage Area (4S-SA1)	BP	Minimum area should be not less than 1500m^2. Area should be sloped (six degree is ideal)	YES
Single Source Separate Stockpiles	Storage Area (4S-SA2)	BP	Treatment of the surface area (no water, no clay)	YES
Single Source Separate Stockpiles	Storage Area (4S-SA3)	BP	Permeable to air roof with permeable to air membrane	NO
Single Source Separate Stockpiles	Stockpiling (4S-S1)	BP	Stockpile must have conical shape with maximum height of 6 m	YES
Single Source Separate Stockpiles	Stockpiling (4S-S2)	R	Searching for deleterious materials (EN 12697-42) Sampling according to EN 932-1	NO
Single Source Separate Stockpiles	Stockpiling (4S-S3)	R	Determining aggregate grading (EN-13043) Sampling according to EN 932-1	NO
Single Source Separate Stockpiles	Stockpiling (4S-S4)	R	Determining binder content (EN 12697-1) Sampling according to EN 932-1	YES
Crushing & Fractioning	Preliminary Screening (CF-PS1)	BP	Preliminary screening of the finer particles by a suitable sieve (3/16 ASTM series or equivalent)	NO
Crushing & Fractioning	Before & After analysis of RAP gradation (CF-BAG1)	BP	Gradation control before & after the in line crusher to determine the RAP aggregate size (within 1B&A analysis 2 samples for RAP source)	NO
Crushing & Fractioning	Number of Screening (Sieves) Unit (CF-NSU1)	BP	The Plant must have 3 screening unit at least, typically 3/4, 3/8, 3/16 (ASTM series or equivalent)	NO
Batch Plant	Drying RAP (BP-D2)	BP	The plant must have a rotary drum dryer with recycling ring (T=110÷130°C)	YES
Warm Recycling	Mixing Time Control (WR-MTC1)	BP	Verifying the mixing time is within the range 25÷90 s	YES
Warm Recycling	Emission Control (WR-EC1)	R	Verifying the pollutant emission according to UE Directive 75/2010	YES

RR = 0.52.

Conclusions

As expected the stage of the process concerning the mixing plant results strategic to declared objectives. In fact the basic rules for a generic process path are equal in average to 16 while the basic rules for agency and construction enterprise are 14 and 11 respectively.
This matter is even more evident by considering the total weight value of the operations regarding the generic path:
25 for mixing plant, 11 for agency and 12 for enterprise.

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The University of Nottingham

UNIVERSITÀ DEGLI STUDI DI PALERMO