SPENS Final seminar
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A methodology for testing and implementing crushed concrete in road construction

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Introduction

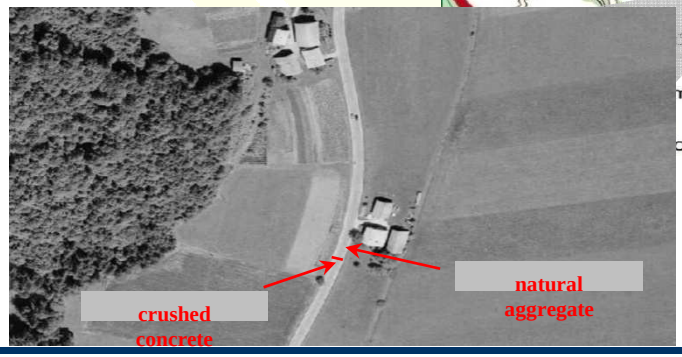
- The use of alternative materials is very important for preservation of the environment.
- Use of recycled materials in civil engineering has been already more or less accepted in a number EU countries, while in New Member States this is still at an early stage.
- Overall all answers have not yet been obtained to many questions linked to the assessment of the engineering performances of alternative materials, and their effects on the environment.
- Part of the SPENS project was to implement concrete building rubble for unbound layers as a substitute for stone aggregate in road construction.

Objectives

- To implement concrete building rubble for unbound layers as a substitute for stone aggregate in road construction.
- Asses suitability of crushed concrete on basis of laboratory testing and long term field monitoring.
- Comparison of behaviour of crushed concrete and natural aggregate under real environmental conditions (traffic loads, temperature changes, precipitation).
- To asses influence of crushed concrete use in road construction on the environment (possible negative effects?).
- Preparation of the test section.

Test section

- R1-216/1367 Iva



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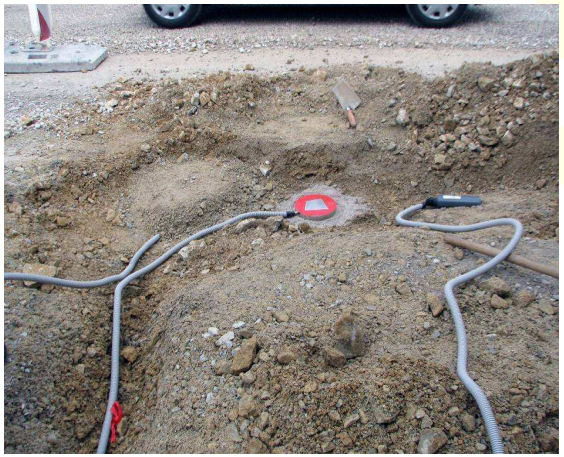

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- For assessment of the environmental acceptability also pore water collectors were built in.

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- Fo
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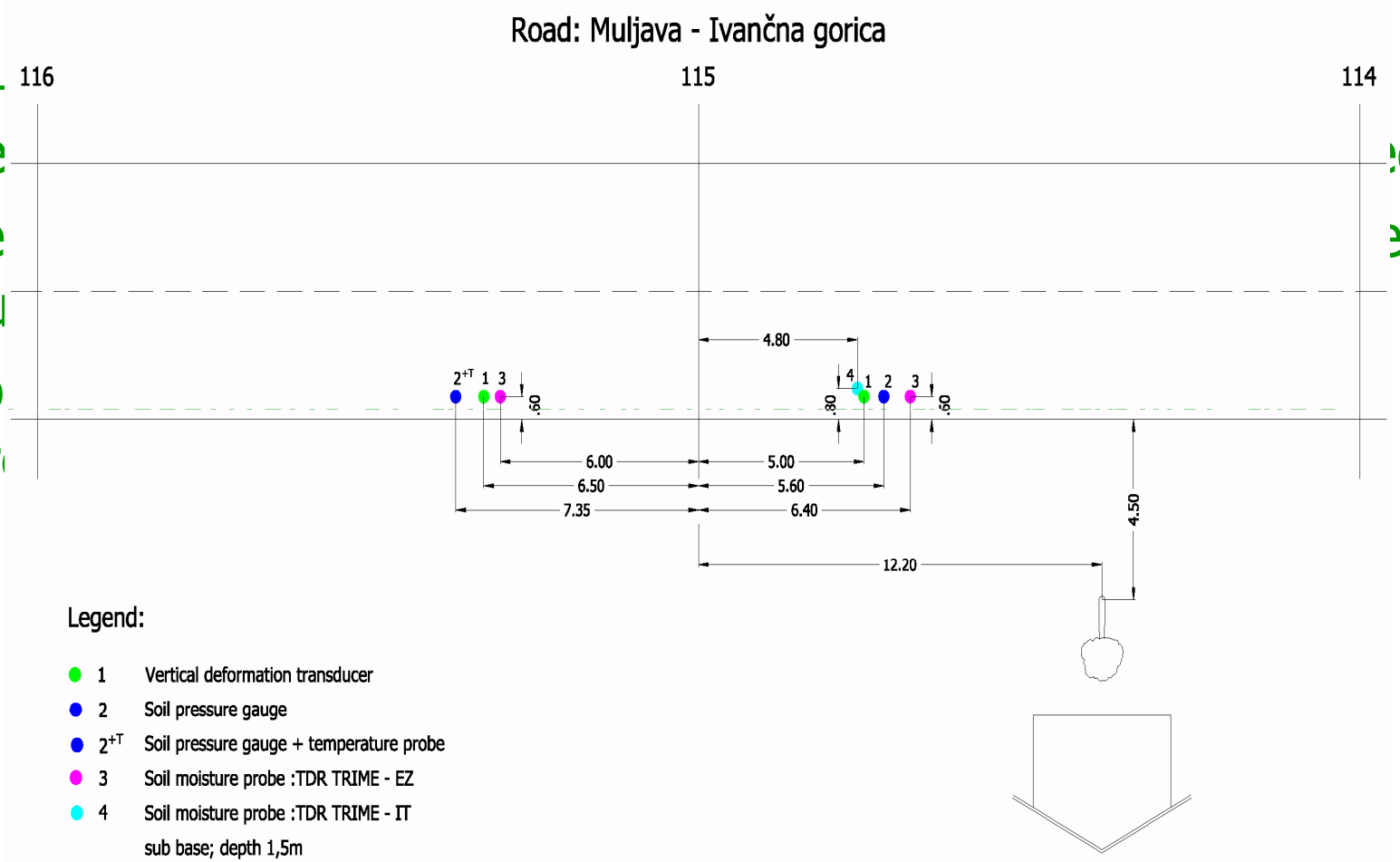

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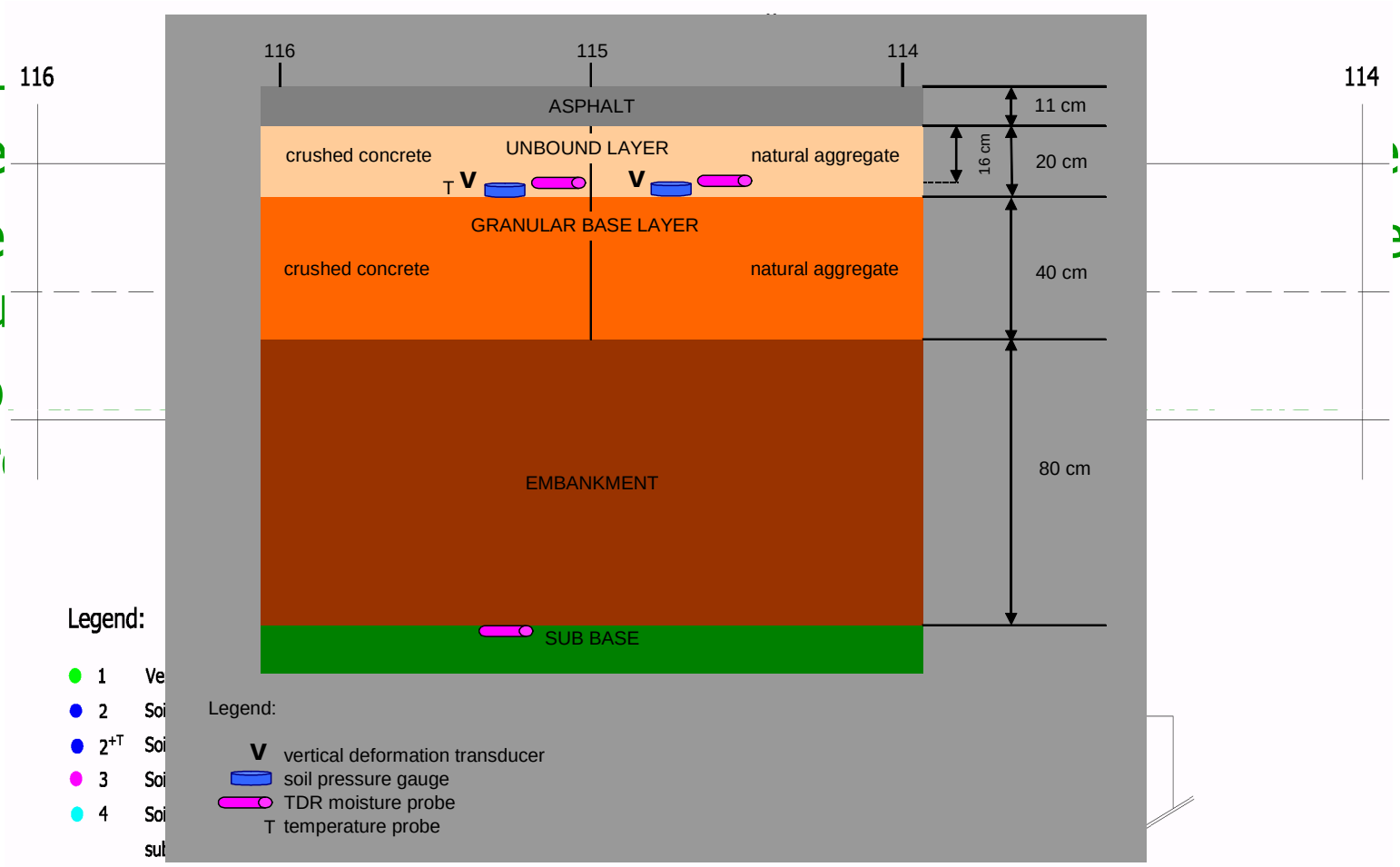

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- Before reconstruction the test section was badly damaged
- Section was instrumented with TDR probes, soil pressure gauges, vertical deformation sensors
- For assessment of the environmental acceptability also pore water collectors were built in.
- At preparation of the test section besides field measurements also samples of the unbound materials (crushed concrete, natural aggregate) and sub base were taken for further laboratory investigations.

Laboratory tests

- Basic tests: grading, Proctor test (maximum dry density, optimum moisture content), sand equivalent, Methylene blue

Material	Classi-ficati-on	Moisture content	Atterberg limits		Plasti-city index	Consis-tency index	Grading				Proctor		Density		Sand equivalent	Methylen blue test	Absorption of water
													dry	specific			
		W_0	W_p	W_l	I_p	I_c	C_u	C_c	<0,02	<0,063	W_{opt}	$\rho_{d\,max}$	ρ_d	ρ_s	SE_4	MB	WA_{24}
		%	%	%	%				%	%	%	kg/m^3	g/cm^3	g/cm^3	%	$g_{dye}/kg_{0-2\,mm}$	%
CLAY (sub base)	CH	23.8	21.6	40.5	18.9	0.9	14.7	0.7	40.8	64.1	19.1	1681 Standard Proctor	1.54				
NATURAL AGGREGATE (unbound layer)	GW	0.8	non plastic				2.1	17.3	2.4	4.5	3.93	2267 Modified Proctor			28	3.0	
CRUSHED CONCRETE (unbound layer)	GW	7.7	non plastic				34.0	1.9	1.8	5.1	9.95	2237 Modified Proctor	2,98 for 0-4 mm 2,93 for 4-32 mm	3.12	42	0.7	6.3

Laboratory tests

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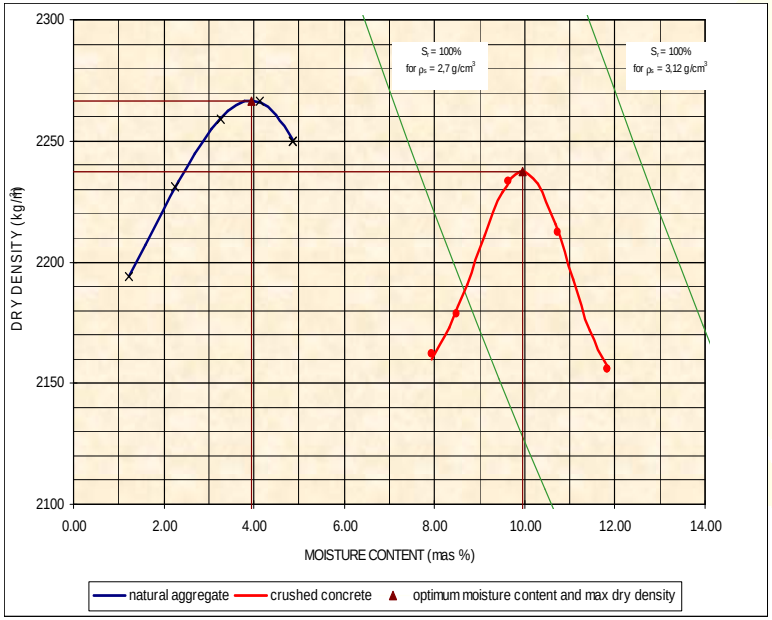
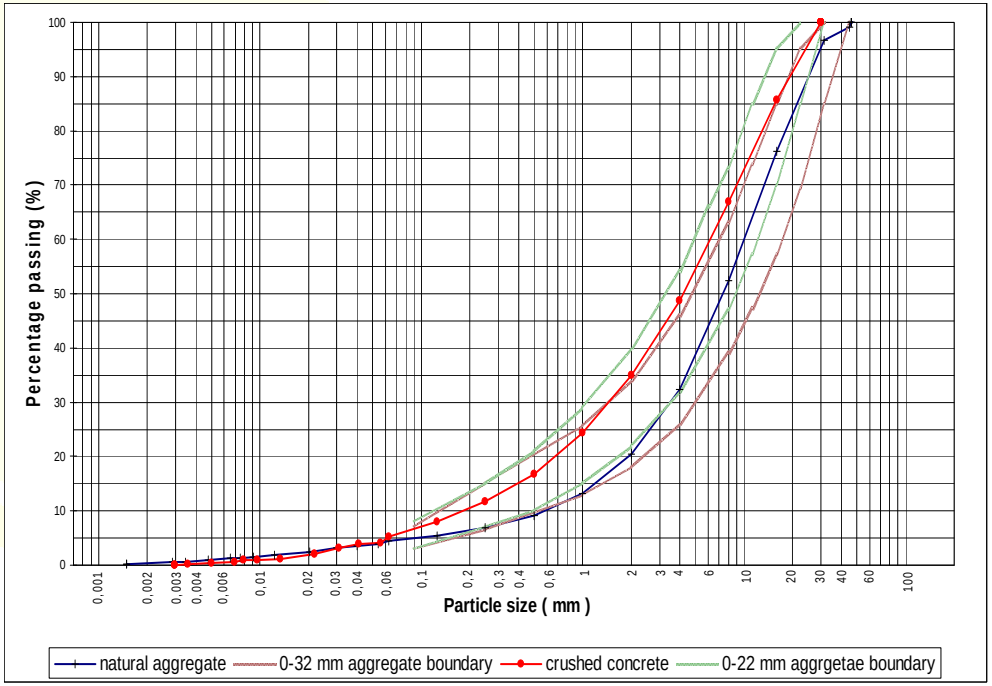


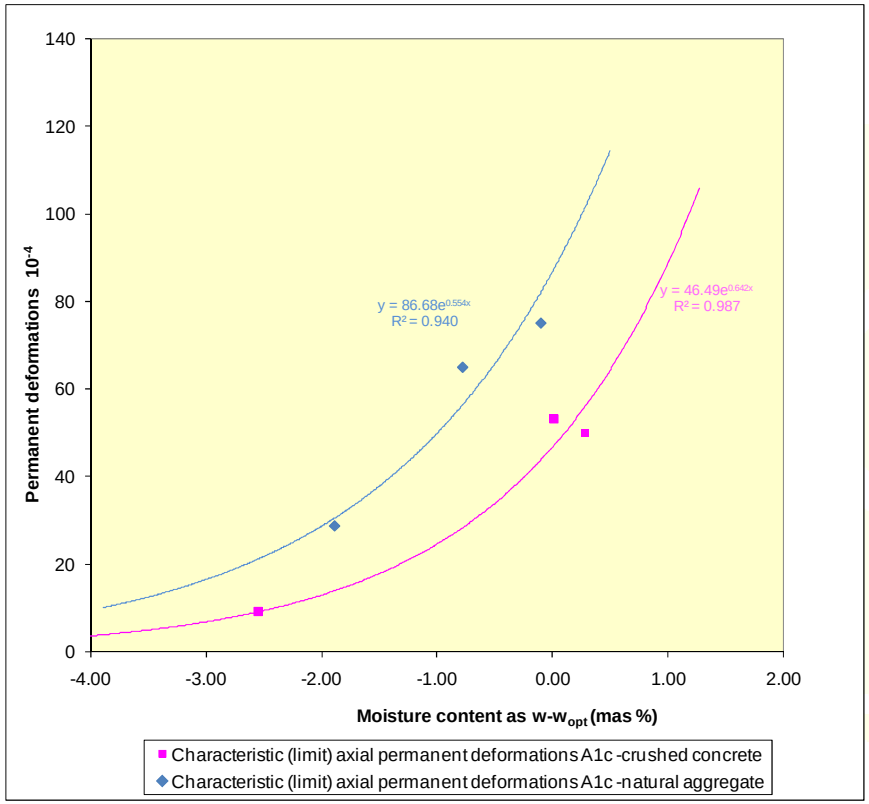


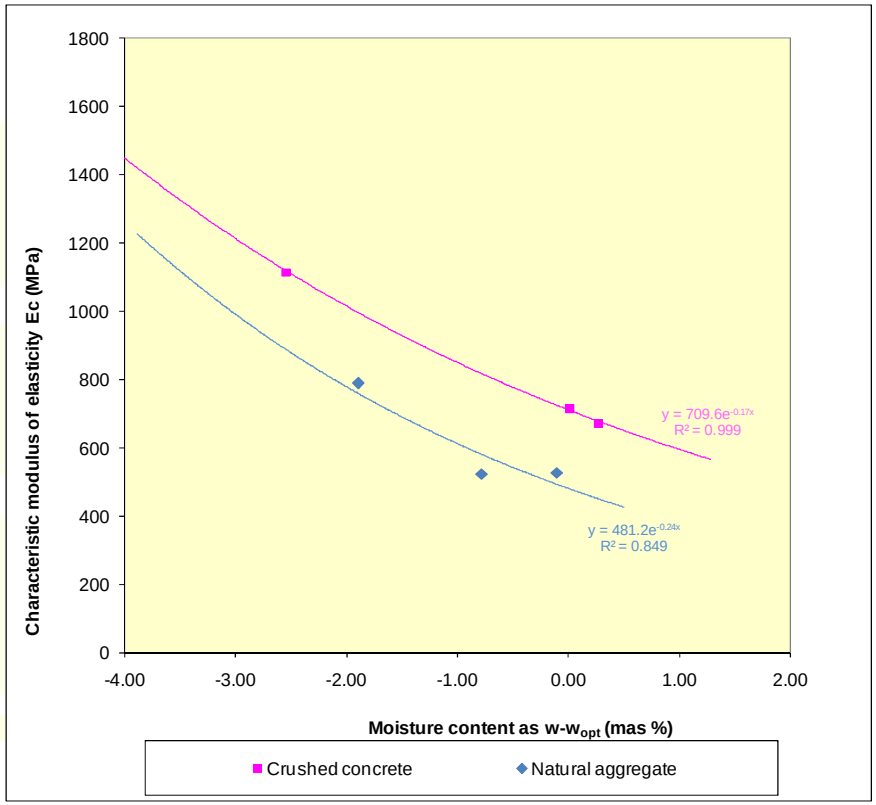
Laboratory tests

- Basic tests: grading, Proctor test (maximum dry density, optimum moisture content), sand equivalent, Methylene blue
- Advanced test: Repeated load triaxial tests (RLT) - French standard procedure NF P98-235-1

Sample		ρ_d kg/m^3	$\rho_{d\,max}$ kg/m^3	$\rho_d / \rho_{d\,max}$ (%)	w (%)	w_{opt} (%)	$w-w_{opt}$ (%)	ε_1^{p*} (20000) 10^{-4}	A_{1c} 10^{-4}	B	E_c MPa	ν
Natural aggregate	NAM 3	2203	2266	97.2	2.04	3.93	-1.89	14.5	28.8	-	789	0.18
	NAM 1	2196	2266	96.9	3.15	3.93	-0.78	33.6	65	-	523	0.15
	NAM 4	2205	2266	97.3	3.83	3.93	-0.10	39.3	75	-	526	0.04
Crushed concrete	DB1	2166	2221	97.5	7.43	9.97	-2.54	4.5	9	-	1115	0
	DB1	2203	2221	99.2	9.99	9.97	0.02	35.9	53	0.22	713	0
	DB3	2136	2221	96.2	10.25	9.97	0.28	24.8	50	-	670	0.2

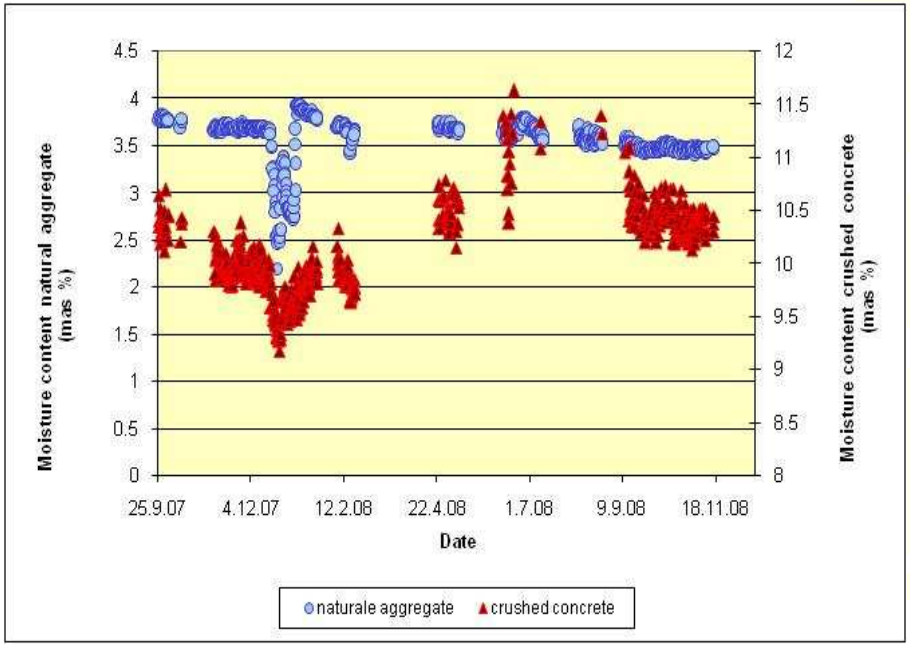
Laboratory tests

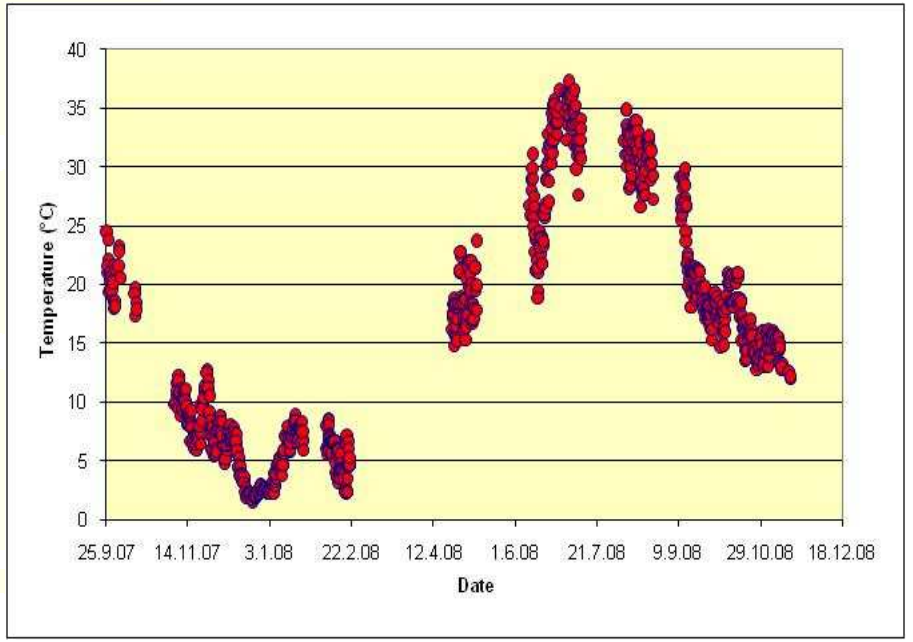




Field measurements

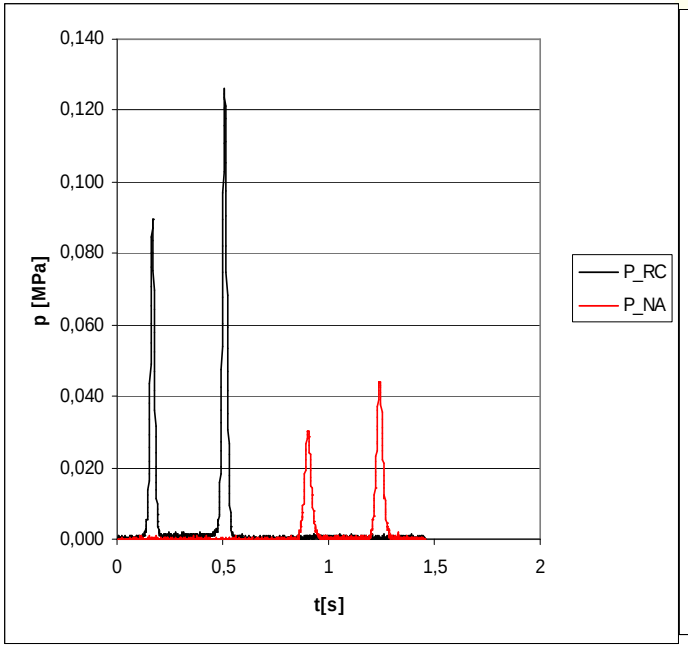
- Moisture content and temperature of unbound layers were monitored

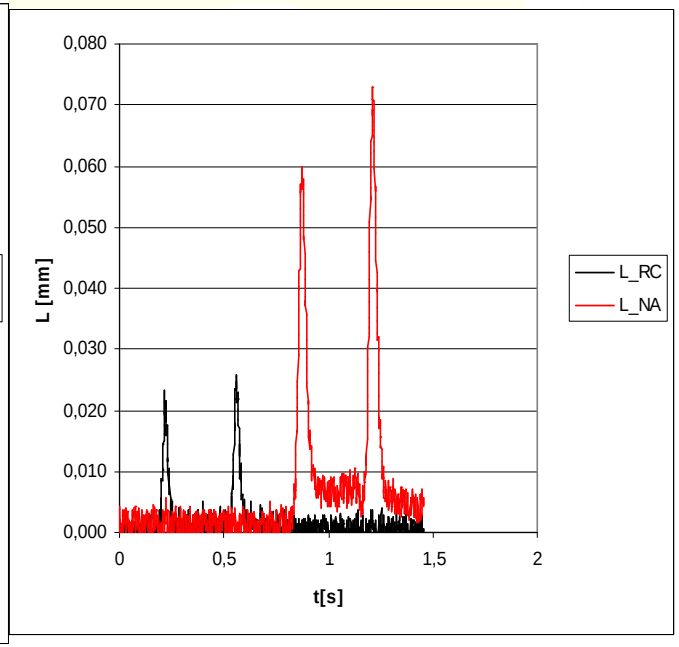


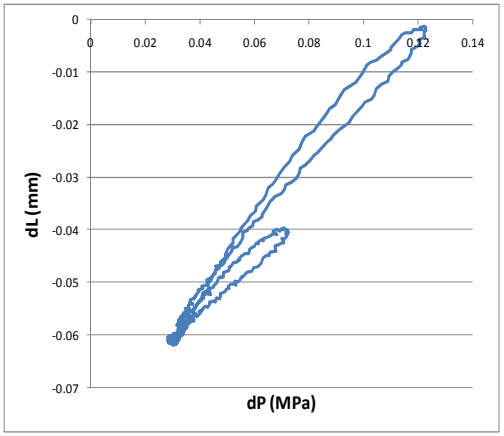


Field measurements

- Moisture content and temperature of unbound layers were monitored
- Measurements of stress and deformation in unbound layer at each vehicle pass







E = σ/ε = dp/(dL/100)

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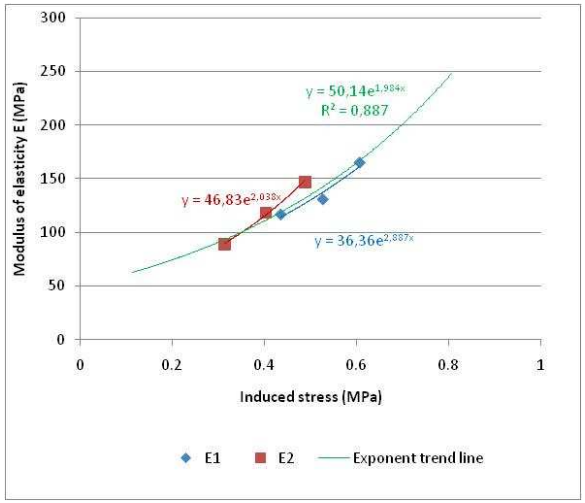

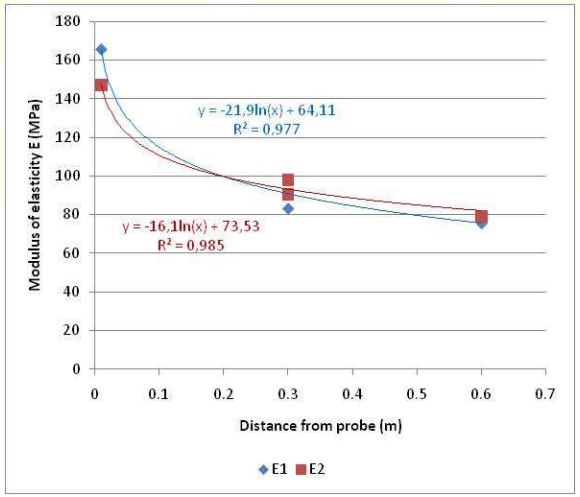

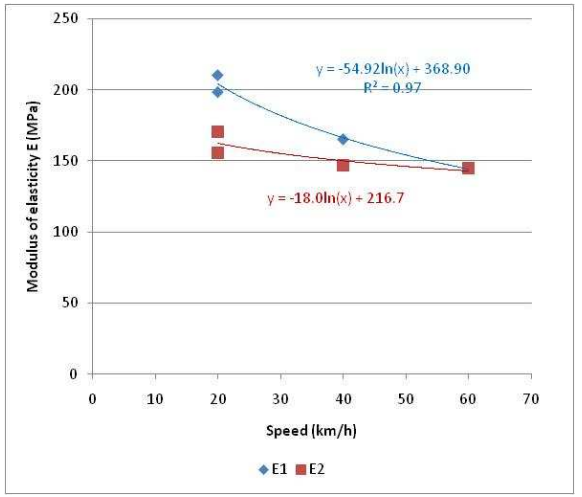

Field measurements

- Moisture content and temperature of unbound layers were monitored
- Measurements of stress and deformation in unbound layer at each vehicle pass
- Pore water quality

Sampling date	Parameter		Crushed concrete 1RC	Crushed concrete 2RC	Natural aggregate 1NA	Natural aggregate 2NA
12.10.2007	pH		9.7	9.7	7.5	7.4
	Hg	mg/L	<0,001	<0,001	<0,001	<0,001
	Zn		<0,4	<0,4	<0,4	<0,4
	Total Cr		<0,3	<0,3	<0,3	<0,3
	Ni		<0,1	<0,1	<0,1	<0,1
	Cu		0.2	<0,1	<0,1	<0,1
	Pb		<0,1	<0,1	<0,1	<0,1
	Cd		<0,1	<0,1	<0,1	<0,1
	As		<0,1	<0,1	<0,1	<0,1
5.6.2008	pH		9.7	9.7	7.5	7.4
	Hg	mg/L	<0,001	<0,001	<0,001	<0,001
	Zn		<0,4	<0,4	<0,4	<0,4
	Total Cr		<0,3	<0,3	<0,3	<0,3
	Ni		<0,1	<0,1	<0,1	<0,1
	Cu		0.2	<0,1	<0,1	<0,1
	Pb		<0,1	<0,1	<0,1	<0,1
	Cd		<0,1	<0,1	<0,1	<0,1
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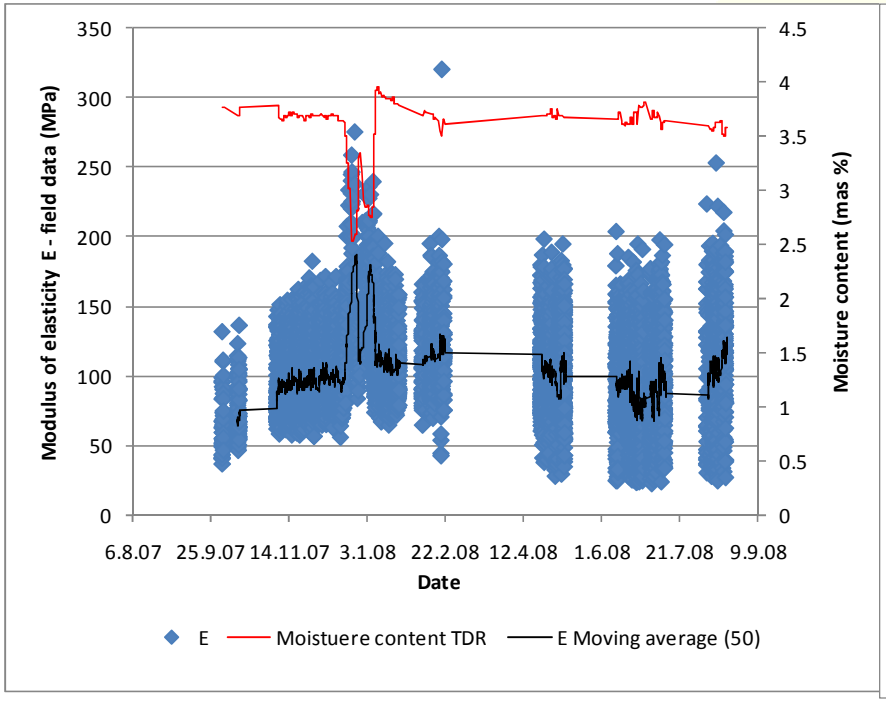
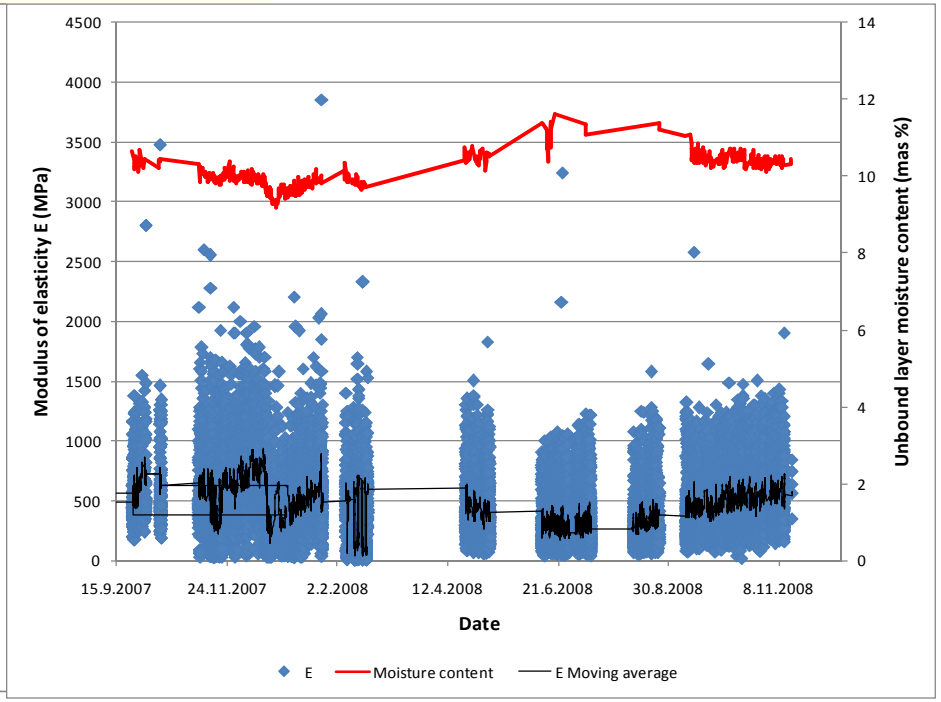
Results and analyses

Influence of moisture content changes (environment) on Changes of modulus of elasticity (stiffness) of unbound layers



Natural aggregate



Crushed concrete

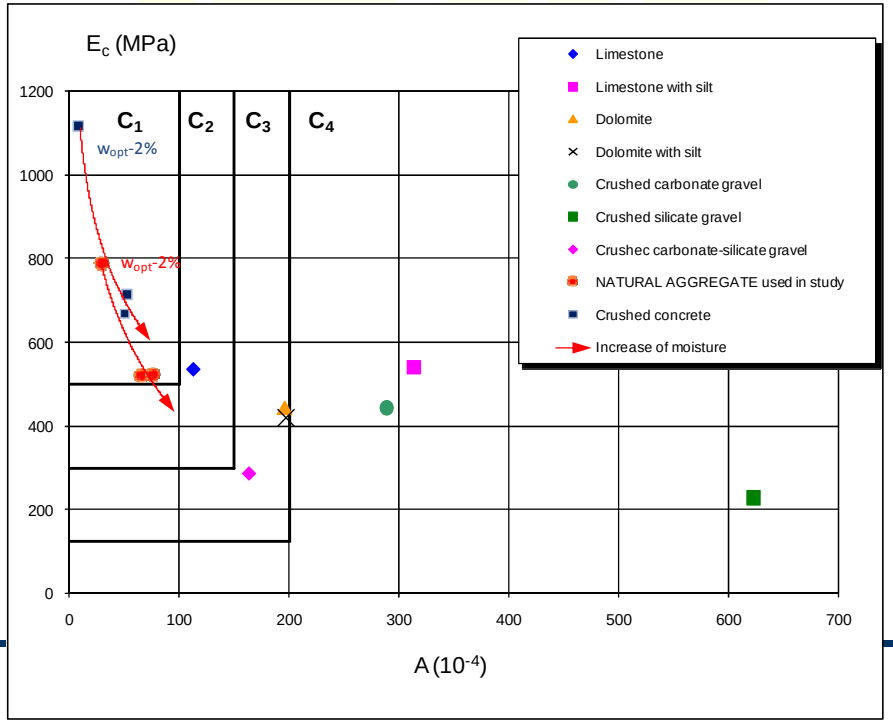
Conclusions

Moisture content or water in unbound layers has a big influence on material behaviour.

With increase of moisture permanent deformations are increasing while modulus of elasticity is decreasing.

Conclusions

- Crushed concrete exerts lower permanent deformations and lower decrease of modulus of elasticity as natural aggregate in same environmental conditions



Conclusions

- Crushed concrete exerts lower permanent deformations and lower decrease as natural aggregate in same environmental conditions
- Moisture sensitivity and freeze-thaw influences for crushed concrete are lower.
- Some laboratory tests are implying long term improvement of crushed concrete behaviour due to the residual cementation
- Monitoring of the pore water showed no negative effects on the environment

Conclusions

Results of this research showed that crushed concrete can be good and environmentally acceptable replacement for the natural aggregate for construction of the unbound layers.

Of course quality of these materials must be in line with the technical and legislative regulations for intended use and must be subjected to detailed technical and environmental acceptance tests prior to their use.