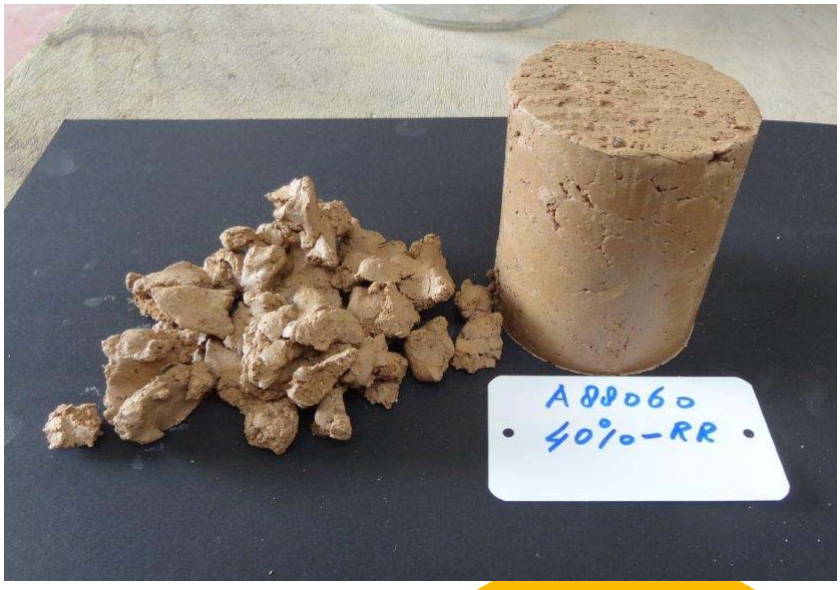

ASSESSMENT OF ROADRAPID FOR USE IN SOIL STABILISATION

Technical, durability and environmental properties

Status **Final report**
Date **09-06-2015**
Report number **A880800/R20150164a**

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Technical, durability and environmental properties

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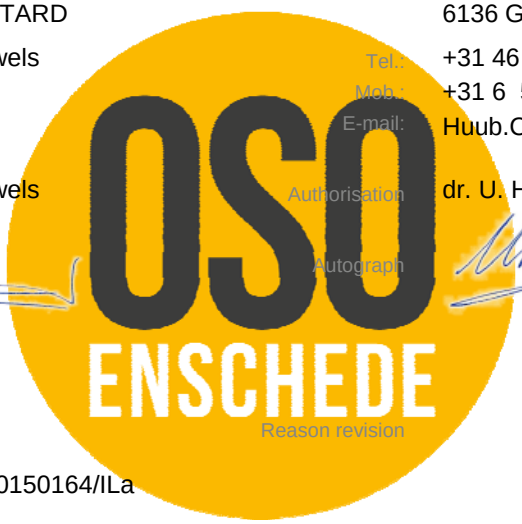

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Date	Report no.	Reason revision
09-06-2015	A880800/R20150164/ILa	

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SUMMARY

Preface
OSO Enschede has developed an additive which, when mixed in place into the soil achieves a functional road stabilisation. For places with a lack of available road construction materials this application is a real advantage. The advantage is also environmentally. Less CO_2 output because of reduced transport is an additional advantage. In order to generate information about the use of RoadRapid for soil stabilisation SGS INTRON is asked to perform a technical and environmental analysis.
The amount of RoadRapid needed for road construction depends on the amount of clay present in the soil. Soil with clay-contents of 20 - 40 % in the can be stabilised with RoadRapid.

Goal
Generate technical and durability information to demonstrate that addition of only small amounts of the additive RoadRapid to the soil results in a road construction with common properties. Addition of RoadRapid to soil will not lead to pollution of the environment.

Executed work
SGS INTRON prepared compacted soil specimens with and without RoadRapid and different clay-contents. The compacted soil specimens were used to determine the technical and durability properties like compressive strength, California bearing ratio, swelling and California bearing ratio after soaking and the environmental properties.

Conclusion
Compaction of soil after addition of RoadRapid and mixing leads to an increase of the bearing strength after 2 and 28 days.
Depending on the clay-content of the soil 0.3 L (20 % clay) to 0.4 L (40 % clay) of RoadRapid per cubic meter of bulk soil has to be used.
Addition of Road Rapid to soil with a clay-content between 20 an 40 % lead to a California bearing ratio similar to that regular construction material like gravel.
Soil with 20 % clay-content stabilised by Road Rapid is not susceptible for water. Soaking of the stabilised soil has no significant effect on CBR-value.
The environmental impact of the use of RoadRapid:

Only a significant increase of the sulphate content was found when adding RoadRapid to the soil.
***A slight increase in the content of some heavy metals** due to the addition of RoadRapid was found.*

Soil with clay-contents of 20 - 40 % (mm/) can be stabilised with RoadRapid (RR)

Property	Age	Clay-content in the soil		
		20 % without RR	20 % with RR	40 % with RR
Compressive strength (MPa)	2 days	0.28	0.87	0.95
	28 days	0.40	1.00	1.05
CBR-value (%)	2 days	8	18	22
	28 days	14	129	132
CBR-value (%) after soaking	56 days (intial hardening during 7 days)	8,9	126	

Remark: No rutting of the road construction will occur if CBR-value is above 10 %.

1. PREFACE

OSO Enschede has developed an additive which, when mixed in place into the soil achieves a functional road stabilisation. For places with no or a lack of large quantities of available road construction materials this application is a real advantage. Economically as well as environmentally, less CO_2 output is realized because of reduced transport. In order to generate information about the use of RoadRapid (RR) for soil stabilisation SGS INTRON was asked to perform technical and environmental analysis.
The amount of RoadRapid needed for road construction depends on the amount of clay present in the soil. The mechanism of stabilisation of the soil by RoadRapid is a reaction between the substances in RoadRapid and the clay-particles in the soil.
Soil with clay-contents of 20 - 40 % (m/m) in the soil can be stabilised with RoadRapid.

The most commonly used properties to define the quality and durability of road constructions are:

- Compressive strength (CS);
- California bearing ratio (CBR):
- Swelling ratio;
- Resistance to soaking.

In order to determine these properties specimens of soil with 2 different contents of clay with and without RoadRapid were made in the SGS INTRON laboratory.

2. PREPARATION OF THE SPECIMENS FOR ANALYSIS

In order to give information about the working range of RoadRapid 2 different soil mixtures were used: 20 % clay and 40 % of clay generated from soil with 57 % clay by adding clean sand (0/4 mm).

For the compaction of the specimens for analysis the European standard EN 13286-2 was used. After 2 and 28 days the compressive strength and California bearing ratio were determined. The specimens were stored at 24 °C sealed in plastic in order to prevent quick evaporation of water.
The immediate bearing index (IBI after 2 days), California bearing ratio and swelling were determined according to the standard EN 13286-47.

For the environmental assessment of the addition of RoadRapid 2 soil samples were analysed for heavy metals and salts (chloride and sulphate).

In the guideline of OSO Enschede the amounts of RoadRapid according the clay-content present in the soil are listed. For soil with 20 % clay 0.3 L RoadRapid per cubic meter of bulk soil is added. For soil with 40 % clay 0.4 L RoadRapid per cubic meter of bulk soil is added. These amounts of RoadRapid are used in this work. The amount of RoadRapid was added to the mixing water. The specimens were prepared at optimum moisture content (OMC).

3. RESULTS

3.1. Technical results

To determine the performance of stabilisation by addition of RoadRapid 2 soil mixtures with different clay-contents were used. The results of compressive strength and California Bearing Ratio are presented in table 1.

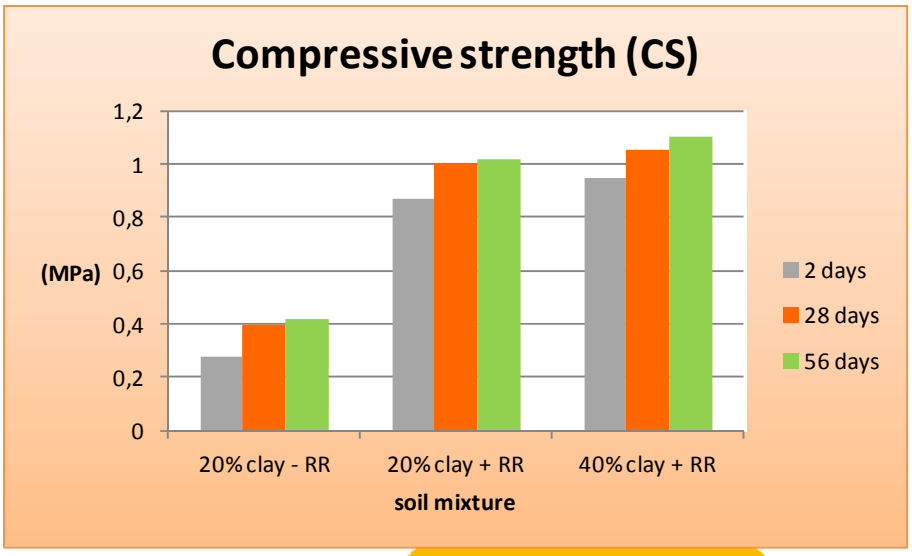
Table 1. Results of compressive strength and California Bearing Ratio tests.

Property	Age	Clay-content in the soil with and without addition of RoadRapid		
		20 % without RoadRapid (RR)	20 % with RoadRapid (RR)	40 % with RoadRapid (RR)
Compressive strength (MPa)	2 days	0.28	0.87	0.95
	28 days	0.40	1.00	1.05
	56 days	0.42	1.02	1.10
California Bearing Ratio (CBR)	2 days	8	18	22
	28 days	14	129	132
	56 days	15	135	139

CBR-values of at least 125 % (after 28 days) are common values for unbound mixtures. For hydraulically bound mixtures (cement based) CBR-values of a minimum of 150 % are common.

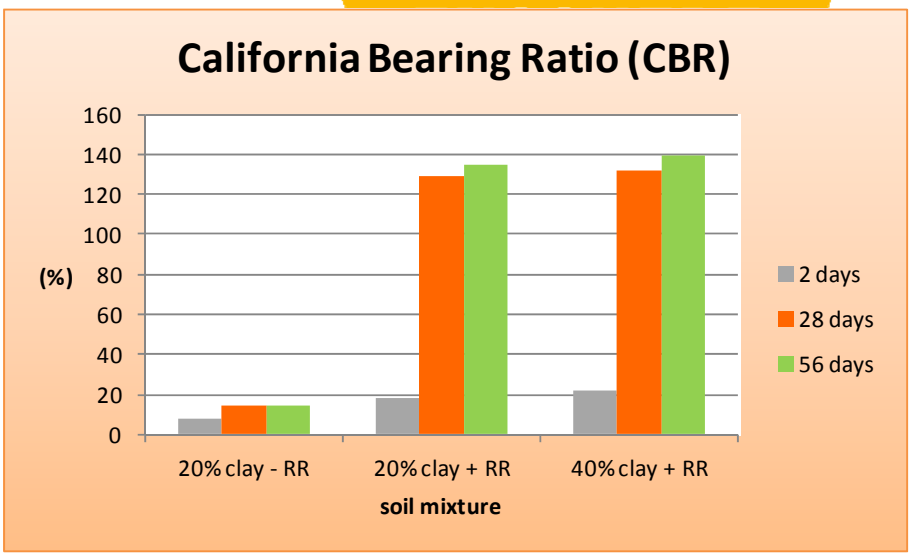
In the figures 1 and 2 below the results of compressive strength and CBR-value are presented separately.

Figure 1: Compressive strength after 2 and 28 days of the 3 soil mixtures.



The compressive strength is limited so cracking of the stabilized soil due to quick hardening is limited.

Figure 2: California Bearing Ratio after 2 and 28 days of the 3 soil mixtures.



Addition of RoadRapid results in an effective increase in CBR-value. Between 28 and 56 days only slight increase of the CBR-value occurs.

Additional information about the use of California Bearing ratio's in relation to road constructions:

In road construction no rutting will occur with CBR-values above 10 %. The CBR-values of the soil mixtures with 20 % and 40 % clay with RoadRapid indicate that no rutting is expected.

In the Netherlands materials for road constructions made of unbound aggregates have to meet a CBR value of 125 % after 28 days.
Comparing this required CBR-value of unbound aggregate mixtures with the CBR-value of soil-stabilisation with RoadRapid with a clay-content between 20 and 40 %, we conclude that the technical quality of the road construction is equivalent.

Soil mixtures with 20 % and 40 % clay-content and added RoadRapid meet these demands. Note that the specimens were prepared at optimum moisture content. If soil stabilisation is performed at moisture contents widely deviated from the optimum moisture content the results of CBR-value will decrease.

3.2. Durability results

In order to give additional information about the durability of soil-stabilisation with addition of RoadRapid the following properties were tested:

- influence of soaking to the CBR-value including moisture uptake;
- swelling of the stabilised soil after contact with water.

The test specimens were exposed to water only 1-sided to simulate contact with water during a rain period. If the water is not easily penetrated in the top layer of the construction the durability of the road stays intact.

Road constructions are normally finished with a bituminous mixture of asphalt. For areas in the world were no asphalt is available addition of RoadRapid to the soil can lead to a stabilised construction which is less susceptible to water during rain fall. To show the susceptibility to water the specimens of compacted soil were exposed to water to detect any possible decrease in CBR-value and the water uptake during the test was determined. The specimens were exposed to water after initial hardening during 7 days.
Additional specimens were tested for swelling in contact with water during 49 days after initial hardening during 7 days.

The results of both tests are presented in table 2.

Table 2: Influence of contact with water on CBR-value and swelling after 56 days of contact.

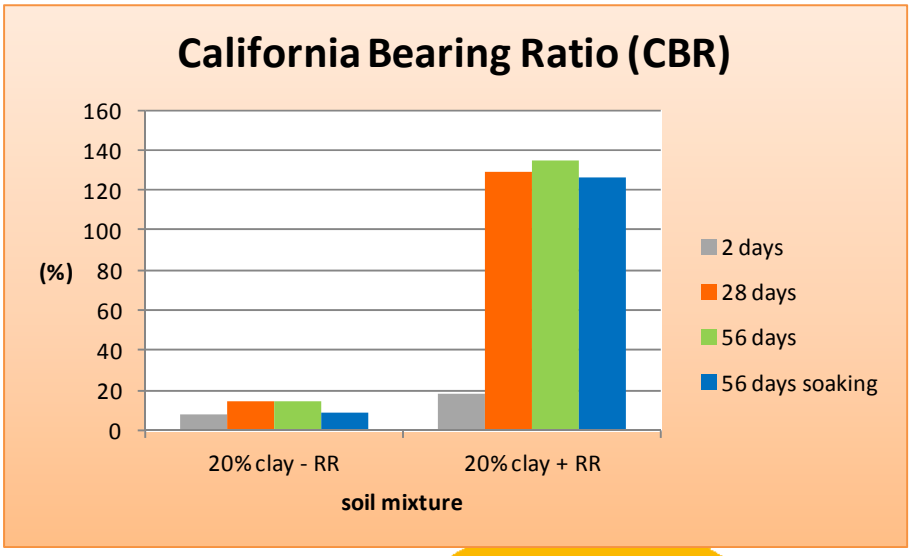
Property	Age	Clay-content in the soil with and without addition of RoadRapid	
		20 % without RoadRapid (RR)	20 % with RoadRapid (RR)
California Bearing Ratio (CBR)	56 days (without soaking)	15	135
	56 days (with soaking)	8.9	126
Moisture uptake (% m/m)	56 days (after soaking)	14.8	5.9
Swelling (% V/V)	56 days (after soaking)	*	1.2
Moisture uptake (% m/m)	56 days (after soaking)	13.7	4.2

Soil with RoadRapid as stabilisation agent appears to be not susceptible to water. The CBR-value does not significantly decease during contact with water. The amount of water uptake for this type of soil with 20 % (m/m) of clay is only about 6% (m/m).

If the soil with 20 % clay is not stabilised with RoadRapid no swelling can be measured because the specimens fall apart as a result of the water uptake.
The swelling of the soil stabilisation is 1.2 % (m/m). The moisture uptake during the 56 days exposure is 4.2 %.

In the figures 3 the influence of water on the CBR-value is presented.

Figure 2: California Bearing Ratio after 2, 28 and 56 days with and without soaking of the soil mixtures.



3.3. Environmental results

To determine the environmental impact of the addition of RoadRapid to soil 2 different soil mixtures were tested for heavy metals and salts (chloride and sulphate). The results of this analysis are listed in table 3.

In the investigated soil mixtures the added sand is known not to contribute to the observed metal content. The observed metal content is therefore due to the original soil and to the RoadRapid. The 40 % clay mixture is expected to have 2 x as high metal content from the original soil as the 20 % clay mixture. The extra amount is attributed to the RoadRapid and is presented as % increase in the last column in table 3.

In the Netherlands there is a regulation (Soil Quality Decree SQD) in which limits are set for heavy metals in soil. If all concentrations of heavy metals are beneath these limits in soil there is no health risk living on this soil. As can be seen in table 3 there is no health risk if RoadRapid was used in soil in the Netherlands.

Table 2: Content of heavy metals and salts in soil mixture with and without the addition of RoadRapid.

Element	Symbol	Content (mg/kg d.s.)		Increase	Maximum limit SQD
		20% clay without RoadRapid	40% clay with RoadRapid	(%)	mg/kg d.s.
Antimony	(Sb)	< 1,0	< 1,0	- -	15
Arsenic	(As)	< 3,0	3,7	- -	27
Barium	(Ba)	77	170	21	550
Cadmum	(Cd)	< 0,17	< 0,17		1,2
Chromium	(Cr)	31	55	- -	62
Cobalt	(Co)	2,5	3,5	- -	35
Copper	(Cu)	6,9	14	3	54
Mercury	(Hg)	0,1	0,23	30	0,83
Lead	(Pb)	8,8	18	5	210
Molybdenum	(Mo)	< 1,0	< 1,0	- -	88
Nickel	(Ni)	15	23	- -	34
Selenum	(Se)	< 2,0	< 2,0	- -	no limits set
Tin	(Sn)	< 3,0	< 3,0	- -	180
Vanadium	(V)	18	39	17	97
Zinck	(Zn)	12	19	- -	200
Chloride	(Cl)	6,8	9,1	- -	no limits set
Sulphate	(SO_4)	60	270	250	no limits set

Only a significant increase of sulphate due to the addition of RoadRapid was determined.

4. CONCLUSION

Compaction of soil after addition of RoadRapid and mixing leads to an increase of the bearing strength after 2 and 28 days.
Depending on the clay-content of the soil 0.3 L (20 % clay) to 0.4 L (40 % clay) of RoadRapid per cubic meter of bulk soil has to be used.

CBR-values of 130 % after 28 days with soil stabilisation by addition of RoadRapid can be reached if well compacted and at optimum moisture contents.

Additional information about the use of California Bearing ratio's in relation to road constructions:

In road construction no rutting is expected with CBR-values above 10 %. The CBR-values of the soil mixtures with 20 % and 40 % clay with RoadRapid indicate that no rutting will occur.

In the Netherlands materials for road constructions made of hydraulic aggregates have to meet a CBR value of 125 % after 28 days. Both mixtures meet these demands. Note that the specimens were prepared at optimum moisture content. If the soil stabilisation is performed at moisture contents widely deviating from the optimum moisture content the results of CBR-value will decrease.
Addition of Road Rapid to soil with a clay-content between 20 and 40 % (m/m) lead to a California bearing ratio similar to that regular construction material like gravel.

Soil with 20 % clay-content stabilised by Road Rapid is not susceptible to water. Soaking of the stabilised soil has no significant effect on CBR-value.

The environmental impact of the use of RoadRapid:

Only a significant increase of sulphate content is determined when adding RoadRapid to the soil.
A slight increase in some heavy metals due to the addition of RoadRapid is determined.

APPENDIX A: ANALYSISREPORT 15.0245

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Analyserapport

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Datum	:	13 februari 2015
Betreft	:	Onderzoek Road rapid
Uw code	:	A880800
Laboratoriumnummer	:	150245
Monsterneming	:	30-1-2015 door de opdrachtgever
Periode onderzoek	:	3-2-2015 t/m 13-2-2015

Monstergegevens

Monsternummer	Monstertype	Monstercode	Acceptatiedatum
1	klei	klei	3-2-2015

Analysemethoden

Analyse	Analysetechniek	Methode	Q	u
Analysemonster gloeiverlies		AP04-V	Q	
Analysemonster lutum		AP04-V	Q	
Droge stof 105°C veldvochtig monster	gravimetrie	AP04-SB-I	Q	
Lutum (fractie < 2 µm)	gravimetrie	NEN 5753, AP04-SG-III	Q	
Organisch stof (gloeiverlies 550°C)	gravimetrie	NEN 5754, AP04-SG-IV	Q	

Q = geaccrediteerd door RvA, u = uitbesteed bij onderaannemer, Qu = geaccrediteerd bij de onderaannemer

Resultaten

Analyse	Eenheid	1
Droge stof 105°C veldvochtig monster	%(m/m)	77,69
Organisch stof	%(m/m)	0,8
Lutum	%(m/m)	55

Opgesteld door: ing. A. Meijs
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Geautoriseerd door: ing. W. Ubachs
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TESTING
RvA L 017

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Informatie over de geschiktheid van de monsters voor analyse

SGS INTRON is conform internationale voorschriften (NEN-EN-ISO/IEC 17025) verplicht te controleren of aangeboden monsters geschikt zijn voor het beoogde onderzoek en moet borgen dat monsters niet achteruit gaan voordat het gehalte is zekergesteld. Het vereist daarom ook dat de leveranciers van monsters ze tijdig en op een juiste wijze verpakt en geconserveerd aanleveren bij het laboratorium.

Er zijn geen verschillen met de richtlijnen geconstateerd die mogelijk de betrouwbaarheid van de resultaten van onderstaande monsters of analyses hebben beïnvloed.

Het monster is niet geconserveerd aangeleverd.

Betreft monsters:	

Het monster is voor de volgende analyse in een ongeschikte verpakking aangeleverd.

Betreft monsters:	

De conserveringstermijn is voor de volgende analyse overschreden.

Analyse(s)	monster(s)

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WHEN YOU NEED TO BE SURE