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Position Paper on the Status of Application of Hydraulic Road Binders in Kenya and Study of the Potential

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Acronyms and Abbreviations Used in this Paper

AASHTO	American Association of State Highway and Transportation Officials
BCL	Bamburi Cement Ltd.
BS	British Standard
EN	European Norm
GM	Grading Modulus
HRB	Hydraulic Road Binder
ICL	Initial Consumption of Lime
KEBS	Kenya Bureau of Standards
KeRRA	Kenya Rural Roads Authority
KNWA	Kenya National Workshop Agreement
KS	Kenya Standard
LL	Liquid Limit
LS	Linear Shrinkage
MDD	Maximum Dry Density
MPa	Mega Pascals. (Equivalent to N/mm^2)
OMC	Optimum Moisture Content
OPC	Ordinary Portland Cement
PI	Plasticity Index
PL	Plastic Limit
PMOD	Plasticity Modulus
RDM	Road Design Manual
UCS	Unconfined Compression Strength

Table of Contents

ABSTRACT:

International standards governing the use of Hydraulic Road Binders in road works have been in existence since the year 2000. The uptake of these additions to the menu of stabilizers has been rather slow in Kenya.

In 2014, the Government, through the Kenya Rural Roads Authority, challenged cement manufacturers to offer a low cost product for use in soil stabilization. Consequently, an action plan to develop Hydraulic Road Binders (HRB) for soil stabilization was agreed upon. As an initial step, a local standard for HRBs was to be developed and adopted. This standard was developed expeditiously by stakeholders and Kenya Bureau of Standards as Kenya National Workshop Agreement *KNWA 2569-1:2014 Hydraulic road binders, Part 1: Rapid hardening hydraulic road binders – Composition, specification and conformity criteria*. The document was based on the British European Norm Standard BS EN 13282-1:2013 of the same title.

The pace of incorporation of HRBs into Kenyan construction specifications has been slow, partly due to insufficient local experience in their manufacture and use. Bamburi Cement Limited (BCL) has taken the initiative to help fast-track adoption and use of HRBs by producing two products conforming to international HRB standards. BCL has gone further, in collaboration with a local engineering consultant, to conduct laboratory trials to test the efficacy of these products. Results of the laboratory trials indicate that the products are fit for purpose.

Following the successful laboratory trials, Bamburi Cement Limited is recommending that full-scale field trials be conducted on ongoing road projects with the aim of enriching the laboratory findings and evaluating field performance of the products, all aimed at eventually incorporating their use in Kenya design manuals and specifications for road construction.

1 INTRODUCTION

In July 2014 the Government of Kenya expressed intention to radically increase road construction by rolling 10,000 Km of new paved roads in 5 years through an annuity financing program. This portended a radical shift from the hitherto annual average paved road construction of 250 Km since independence to 2,000 Km. Inherent in the program was a concomitant ambition to reduce overall costs of road construction.

A meeting was held on 25th March 2014 between cement manufacturers and the Director General, Kenya Rural Roads Authority (KeRRA) where the manufacturers were challenged to offer an alternative low cost binder for soil stabilization. The cost of the binder was expected to be lower than conventional stabilization cement (OPC 42.5) by 30%. The outcome of the meeting was an action plan towards the development of Hydraulic Road Binders (HRB) for soil stabilization. It was agreed that a HRB standard to guide the manufacture and testing of the product needed to be formulated and fast tracked. The standard was developed expeditiously by stakeholders and Kenya Bureau of Standards as Kenya National Workshop Agreement *KNWA 2569-1:2014 Hydraulic road binders, Part 1: Rapid hardening hydraulic road binders – Composition, specification and conformity criteria*. The document was based on the British European Norm Standard BS EN 13282-1:2013 of the same title. The BS EN 13282 Part 2 standard incorporating normal hardening hydraulic road binders was not adapted locally owing to its draft status in Europe at that time.

Local road works specifications of cement and/or binders have not kept pace with these developments. As such Hydraulic Road Binders (HRB's) have found limited applications in road works simply because they are not recognized by existing construction specifications. Owing to this reality, concomitant experience in testing, specification and construction with such contemporary cements/binders on road works in Kenya is virtually non-existent. The current Kenya *Standard Specification for Road and Bridge Construction* specifies cements complying to KS 02-21 for Ordinary Portland Cement and KS 02-21 for rapid hardening Portland cement. These standards were based on British Standards that are now superseded and have since been withdrawn. The KS 02 standards have also been locally withdrawn and the most current gazetted cement standard is KS EAS 18-1 Composition *Specification and Conformity Criteria for Common Cement* as adopted from the European Norm Standard EN 197-1 of the same name and harmonised across East Africa. However, cements in KS EAS 18-1 standard with attributes conforming to former BS 12 requirements continue to be specified for use in construction of roads and bridges.

It is against this background that Bamburi Cement Limited set out to undertake research and development on the use of Hydraulic Road Binders in soil improvement and stabilization works in road construction. It is envisaged that the adoption of HRB's would offer an alternative and wider range of products to hitherto used traditional soil treatments with lime and/or cement.

2 OBJECTIVE

The main objective of this paper is to provide performance justification on the use of HRBs for improvement and stabilization of pavement layers alongside CEM I, 42.5 (OPC) on road construction projects in Kenya.

3 LITERATURE REVIEW

3.1 HYDRAULIC ROAD BINDERS (HRB)

Hydraulic Road Binders are cementitious powders produced by factory blending different constituents. When mixed with water, HRB hardens and remains solid.

These mixtures are supplied ready for *in-situ* treatment of materials mainly for sub-bases, capping/base layers and soil embankments.

HRBs have been manufactured for many years globally. They are designed and developed for applications in stabilization and improvement of physical and mechanical properties of soils and various materials used in road works.

3.1.1 HRB constituent materials

HRBs typically consist of Portland cement clinker and other constituents such as:

1. Natural pozzzolanas
2. Natural calcined pozzolanas
3. Limestone
4. Siliceous fly ash
5. Calcareous fly ash
6. Burnt shale
7. Cement kiln dust
8. Retarders etc.

3.1.2 Mechanical, Physical and Chemical requirements of HRBs

HRBs have chemical, mechanical and physical characteristics as well as test processes similar to those of cement. Table 1 is an extract of the Mechanical properties of HRBs and Table 2 Physical requirements as per BS EN 13282 part 1:2013.

Strength Class	Compressive strength, in MPa (N/mm²)		
	At 7 days	At 28 days	
HRB E2	≥5	≥12.5	≤32.5
HRB E3	≥10	≥22.5	≤42.5
HRB E4	≥16	≥32.5	≤52.5
HRB E4 – RS	≥16	≥32.5	-

Table 1: Hydraulic Road Binders Mechanical Requirements

Hydraulic road binder	Fineness % residue by mass 90 µm	Initial setting time min	Soundness (expansion) mm
HRB E	E ≤ 15	≥ 90	≤ 10
HRB E4 – RS	≤ 15	≤ 90	≤ 30

Table 2: Hydraulic Road Binders Physical Requirements

The sulphate content, expressed as the percentage of SO_3 by mass, and determined in accordance with EN 196-2, shall not exceed 4,0 % for most hydraulic road binders. Exceptions with higher sulphate content are allowed for HRB's containing calcareous fly ash, burnt shale or granulated blast furnace slag but with an additional Cs marking.

3.1.3 Benefits of HRBs

Benefits of HRBs include but are not limited to:

1. Generation of energy cost savings by foregoing far-off borrow pits and use of *in-situ* material.
2. Improvement of structural integrity and durability of pavement layers.
3. Optimization/re-use of material already in place.
4. Improvement on open working time compared to OPC CEM I 42.5 specified as 2 Hrs in the Standard Specifications for Road and Bridge Construction.

5. Use in road dust control.
6. Environmentally friendly Green binder with low carbon dioxide emissions during production.
7. Sustainable use of wastes generated by other industries e.g. Fly Ash from power plants burning coal or slag from iron ore processing; these materials are cementitious and enhance cement attributes e.g. chemical resistance, lower thermal Heat of Hydration etc.

The process of treatment and stabilization with HRBs in a road project is similar to use of conventional cement or lime, where dosing consists of spreading, mixing, rolling and curing.

Details of the other Hydraulic Road Binders (HRBs) in use in other countries are attached in Appendix II.

3.1.4 HRBs developed by Bamburi Cement Ltd.

Bamburi cement has developed and obtained certification from Kenya Bureau of Standards for the following HRB's:

1. HRB E3 – Pozzzolana based, 28 day strength ≥ 22.5MPa, ex-Nairobi Grinding Plant
2. HRB E3 – Limestone based, 28 day strength ≥ 22.5MPa, ex-Mombasa Plant

4 LABORATORY TRIALS USING BAMBURI HRBs

4.1 GENERAL

In order to test the efficacy of Bamburi-manufactured HRBs in soil improvement, a series of laboratory trials were conducted by Norken International Engineering and Management Consultants. Candidate soils for improvement included clays, silts and gravels. The candidate soil types and their sources are as tabulated below:

Type of soil	Source
Clay	Emali, Makueni County
Silt	Emali, Makueni County
Mutaho Gravel	Sigalagala, Kakamega County
Masyenze Gravel	Sigalagala, Kakamega County

As a control for purposes of comparison, parallel tests on the same soils were done using ordinary Portland cement (CEM I 42.5).

4.2 STABILIZERS USED

The following three types of stabilizer were used, conforming to the manufacturing standards contained in table 3 below:

1. Ordinary Portland cement – CEM I, 42.5 manufactured at Bamburi Cement Ltd., Mombasa Plant;
2. Roadcem HRB E3 (L) manufactured at Bamburi Cement Ltd., Mombasa Plant;
3. Roadcem HRB E3 (P) manufactured at Bamburi Cement Ltd., Nairobi Grinding Plant.

PARAMETER		UNIT	TYPE OF STABILIZER	
			CEM I 42.5	**HRB E3**
COMPOSITION				
Clinker		%	≥ 95	≥ 20
MECHANICAL REQUIREMENTS				
Fineness		90μm	≤ 10	≤ 15
Initial Setting Time		Min.	≥ 60	≥ 90
Strengths	7-Day	MPa.	≥ 16	≥ 10
	28-Day (Min.)	MPa.	≥ 42.5	≥ 22.5
	28-Day (Max.)	MPa.	62.5	42.5
Soundness		%	≤ 10	≤ 10
CHEMICAL REQUIREMENTS				
Sulphate		%	≤ 3.5	≤ 4.0

Table 3: Manufacturing Standards of the Stabilizers

4.3 TESTS CONDUCTED

4.3.1 Tests on neat (untreated material)

The following tests were carried out on the soil samples before stabilization:

1) Atterberg Limits (BS 1377: Part 2: 1990)
2) Linear Shrinkage (BS 1377: Part 2: 1990)
3) Particle Size Distribution (BS 1377: Part 2: 1990)
4) Organic Matter Content (BS 1377: Part 3: 1990)
5) Compaction Test (AASHTO T 180)
6) Particle Density (BS 1377: Part 2: 1990)
7) CBR Test (4 days soak) (BS 1377: Part 4: 1990)

4.3.2 Tests on stabilized material

In addition, the following tests were conducted on soil samples stabilized with varying quantities of the three types of stabilizer:

1. Atterberg Limits (BS 1377: Part 2: 1990);
2. Linear Shrinkage (BS 1377: Part 2: 1990);
3. Initial Consumption of Lime (ICL) (BS 1924: Part 2: 1990);
4. Compaction test (AASHTO T 180) on samples mixed with stabilizer content = 4%;
5. Unconfined compression (UCS test) at 7 days cure + 7 days soak on specimens moulded dynamically at OMC and MDD and at three stabilizer contents, i.e 2%, 4% and 6%; (BS 1924: Part 2: 1990);
6. Atterberg Limits on stabilized samples after UCS testing; (BS 1377: Part 2: 1990).

5 RESULTS AND ANALYSIS

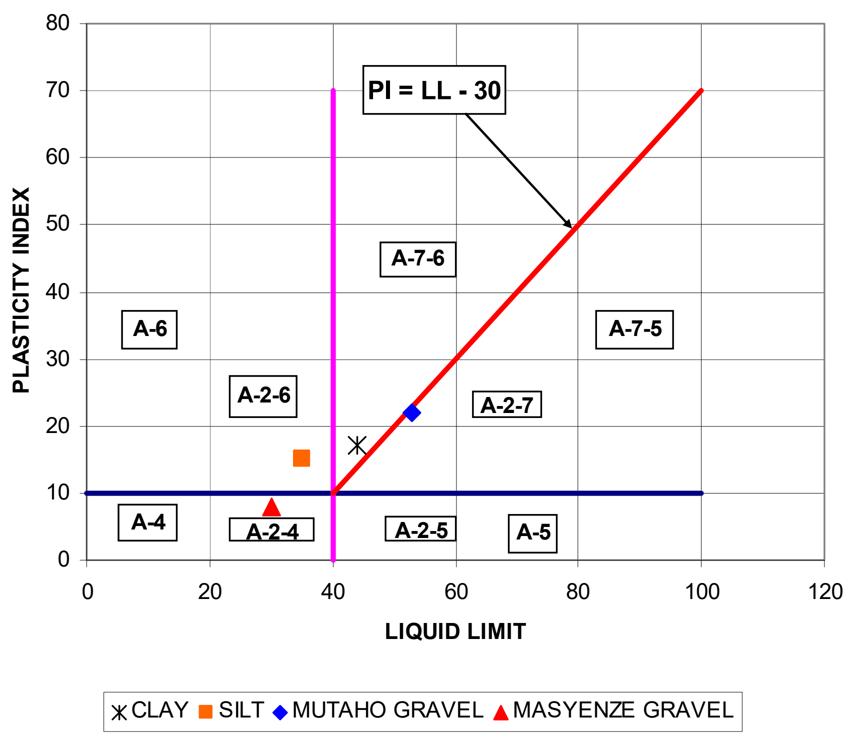
5.1 GENERAL

The results of laboratory trials conducted are attached as Appendix I. Analysis of the results are presented in the sections that follow.

5.2 SOIL CLASSIFICATION

The AASHTO classification of the soils tested is as shown in fig. 1 below.

FIG. 1: AASHTO CLASSIFICATION OF SOILS



5.3 SOIL STRENGTH – STABLIZER CONTENT RELATIONSHIPS

The effect of stabilizer content on the strength of the various soils is shown in the charts below.

FIG. 2: CLAY UCS

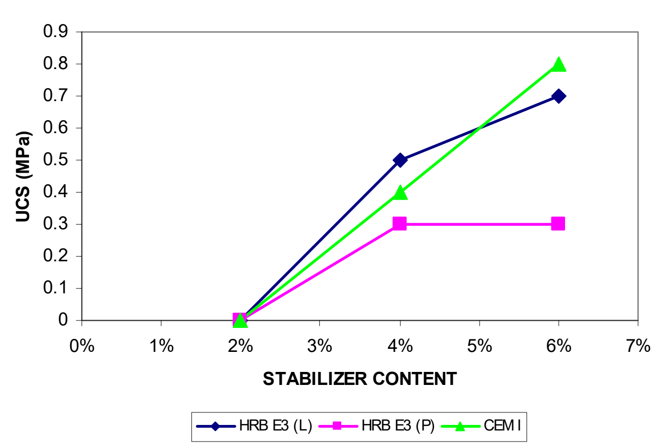


FIG. 3: SILT UCS

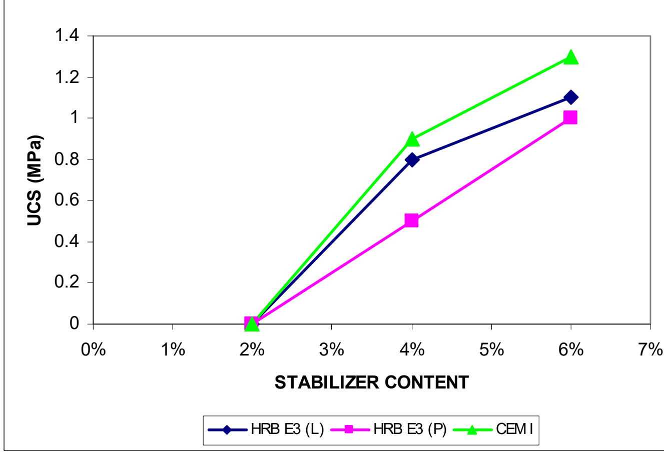


FIG. 4: MUTAHO GRAVEL UCS

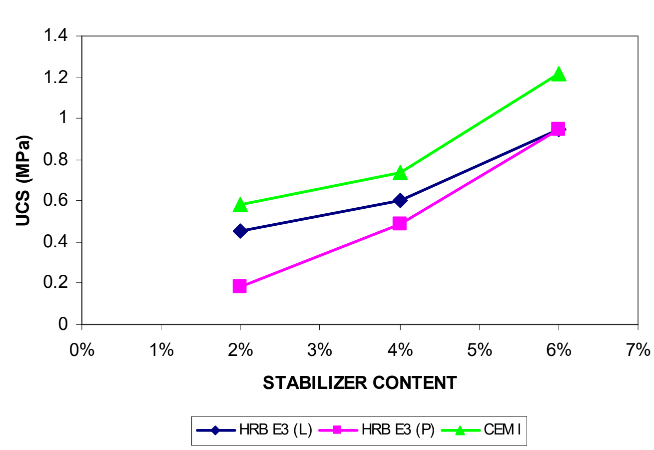
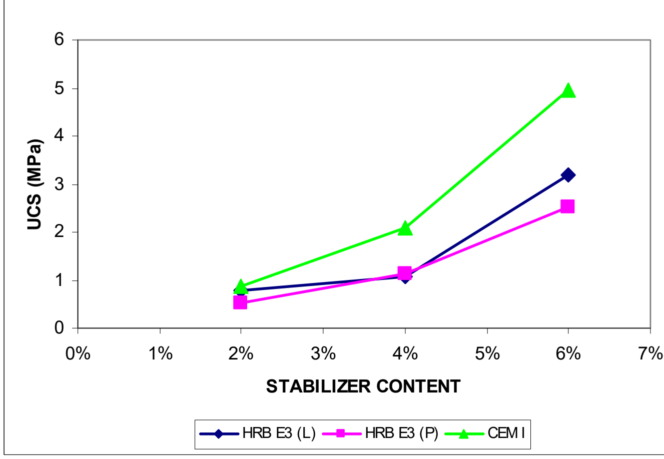
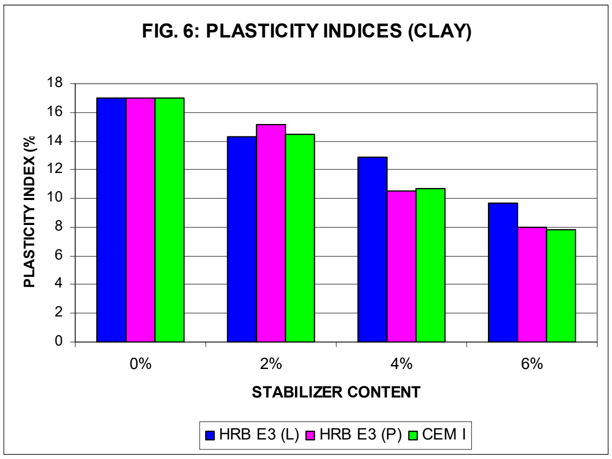


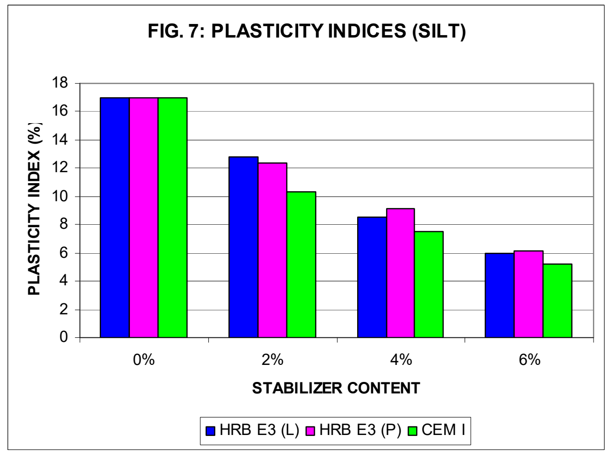
FIG. 5: MASYENZE GRAVEL UCS

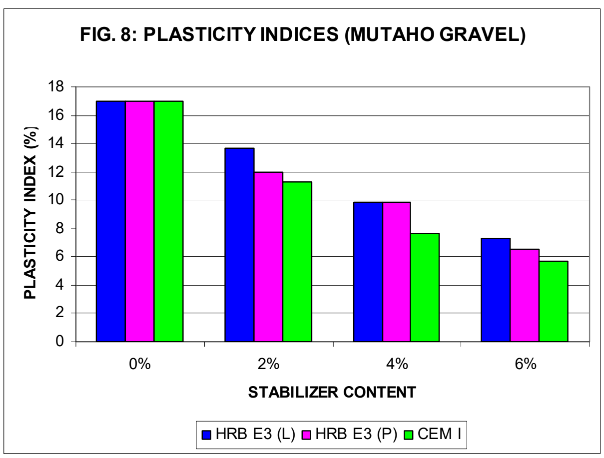


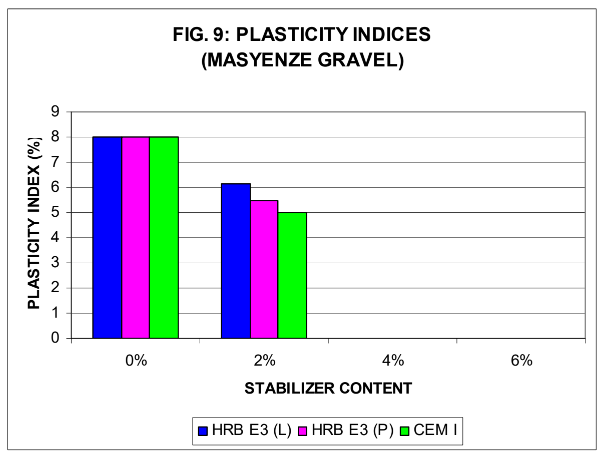
5.4 SOIL PLASTICITY – STABLIZER CONTENT RELATIONSHIPS

The effect of stabilizer content on the plasticity of the various soils is shown in the charts below.









6 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn from analyses of foregoing results:

- That for the HRB formulations tested are effective in enhancement of soil strength, which is a key objective of stabilization;
- That for the HRB formulations tested are effective in the reduction of soil plasticity, which is a key objective of stabilization.

Following laboratory trials presented in this study, we recommend the conduct of full-scale field trials to evaluate in-service performance of soils stabilized with HRB. Such field trials would also evaluate the efficacy of mixing and compaction methods with a view to develop works specifications for these materials.

We further recommend that these trials be conducted under the supervision of the Materials Testing and Research Department of the MoTI on a wider variety of soils countrywide.

7 REFERENCES

1. KNWA 2569-1:2014 *Hydraulic road binders, Part 1: Rapid hardening hydraulic road binders — Composition, specification and conformity criteria*

2 BS EN 13282-1:2013 *Hydraulic road binders, Part 1: Rapid hardening hydraulic road binders — Composition, specification and conformity criteria*

3 THE FRENCH ROAD ENGINEERING COMMITTEE -CFTR (2007). *Treatment of soils with lime and / or hydraulic binders (application to the construction of pavement base layers).* SETRA. Paris, France.

4 THE FRENCH ROAD ENGINEERING COMMITTEE -CFTR (2004). *Treatment of soils with lime and / or hydraulic binders (application to the construction of fills and capping layers).* SETRA. Paris, France.

5 HOWARD ROBINSON. *Hydraulically Bound Materials*. Tarmac, BLA Seminar, 2007.

6 BRITISH STANDARDS INSITUTION (2004). *Part 13: Soils treated by hydraulic road binders*. BS EN 14227, London, UK.

7 THE BRITISH IN-SITU CONCRETE PAVING ASSOCIATION (2005). Draft: *Code of Practice for the Design of Road Pavement*. CSIR, Pretoria, South Africa, for SATCC.

8 SOUTH AFRICAN TRANSPORT AND COMMUNICATION COMMISSION – SATCC (1998). Technical Data Sheet: *Cement and other hydraulically Bound Mixtures.* BRITPAVE, Surrey, UK.

9 NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT (NCASI) .2003. *Beneficial Use of Industrial By-Products*. Special Report, Washington, USA.

10 LAFARGE RESEARCH CENTER TEST REPORT. *Kenya – Evaluation of cements and HRB LCR-RES-249 - Version : 1*. N. Richard, Lafarge Research Center, Lyon, France

APPENDIX I : TEST RESULTS SUMMARIES

SUMMARY SHEET
Tests on Clay

Sample reference	Atterberg Limits LL (%)	PL (%)	PI (%)	LS (%)	PM	Particle size distribution (%) Percentage passing sieve size (mm) 20	2	0.425	0.075	Grading Modulus GM	AASHTO Class	Organic Content (%)	Compaction T 180 MDD (kg/m^3)	OMC (%)	CBR at 100% MDD (%)	Swell (%)	ICL (%)
Before Stabilization																	
SAMPLE No. 1	44	27	17	8	1581	100	98	93	83	0.3	A-7-6	0.60	1628	23	15(26)	0.5	4.7
SAMPLE No. 2	43	25	18	8	1674	100	98	93	83	0.3	A-7-6	1.54	1633	23	17(26)	0.5	4.7
SAMPLE No. 3	45	28	17	8	1598	100	98	94	79	0.3	A-7-6	0.90	1638	22.7	20(24)	0.4	3.8

After Stabilization

Sample		UNCONFINED COMPRESSION (7DC + 7DS) 1 MPa	2 MPa	3 MPa	MEAN MPa	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	LS (%)
SAMPLE No. 1									
With HRB E3 (L)	2%	COLLAPSED				41	26	15	8
	4%	420	657	536	538	40	26	14	7
	6%	735	729	409	732	37	27	10	5
With HRB E3 (P)	2%	COLLAPSED				41	27	14	7
	4%	398	215	580	489	38	27	11	6
	6%	204	215	COLLAPSED	140	33	24	9	4
With CEM I	2%	COLLAPSED				37	24	13	6
	4%	459	365	331	385	35	25	10	5
	6%	967	707	823	832	34	26	8	4
SAMPLE No. 2									
With HRB E3 (L)	2%	COLLAPSED				39	24	15	7
	4%	425	525	503	484	39	25	14	7
	6%	552	503	834	630	35	24	11	5
With HRB E3 (P)	2%	COLLAPSED				40	25	15	7
	4%	99	304	238	271	37	25	12	6
	6%	425	409	COLLAPSED	417	33	24	9	4
With CEM I	2%	COLLAPSE				38	23	15	7
	4%	398	331	431	387	36	22	14	7
	6%	890	801	702	798	34	23	11	6
SAMPLE No. 3									
With HRB E3 (L)	2%	COLLAPSED				34	24	10	5
	4%	470	343	525	446	35	24	11	5
	6%	751	912	663	775	33	25	8	4
With HRB E3 (P)	2%	COLLAPSED				41	26	15	7
	4%	243	503	COLLAPSED	373	35	24	11	6
	6%	613	541	155	577	32	24	8	4
With CEM I	2%	COLLAPSED				37	23	14	7
	4%	497	425	536	486	33	26	7	3
	6%	945	796	558	766	36	28	8	4

SUMMARY SHEET
Tests on Silt

Sample reference		Atterberg Limits					Particle size distribution (%)				Grading	AASHTO	Organic	Compaction T 180		CBR		ICL
Sample reference		LL	PL	PI	LS	PM	Percentage passing sieve size (mm)				Modulus	Class	Content	MDD	OMC	at 100% MDD	Swell	
		(%)	(%)	(%)	(%)		20	2	0.425	0.075	GM		(%)	(kg/m^3)	(%)	(%)	(%)	(%)
Before Stabilization																		
SAMPLE No. 1		34	19	15	7	1170	100	97	78	44	0.8	A-6	1.24	1828	14.0	27(36)	0.3	2.9
SAMPLE No. 2		35	19	16	8	1232	100	97	77	44	0.8	A-6	0.90	1829	13.9	30(36)	0.2	2.7
SAMPLE No. 3		35	20	15	7	1170	100	97	78	43	0.8	A-6	1.54	1829	14.0	29(36)	0.2	3.3
After Stabilization																		
SAMPLE No. 1																		
		UNCONFINED COMPRESSION (7DC + 7DS)					**ATTERBERG LIMITS**				ATTERBERG LIMITS							
		1	2	3	MEAN	LL	PL	PI	LS		LL	PL	PI	LS				
		MPa	MPa	MPa	MPa	(%)	(%)	(%)	(%)		(%)	(%)	(%)	(%)				
With HRB E3 (L)	2%	COLLAPSED				32	18	14	7		32	18	14	7				
	4%	985	1050	1112	1049	25	19	6	5		25	19	6	5				
	6%	1398	845	972	1072	24	18	6	3		24	18	6	3				
With HRB E3 (P)	2%	COLLAPSED				31	18	13	7		31	18	13	7				
	4%	547	199	448	498	28	18	10	5		28	18	10	5				
	6%	1315	486	1221	1268	26	20	6	3		26	20	6	3				
With CEM I	2%	COLLAPSE				31	21	10	5		31	21	10	5				
	4%	1298	1215	1138	1217	25	17	8	4		25	17	8	4				
	6%	1348	1315	1359	1341	22	17	5	3		22	17	5	3				
SAMPLE No. 2																		
With HRB E3 (L)	2%	COLLAPSED				32	19	13	7		32	19	13	7				
	4%	409	1221	COLLAPSED	543	27	18	9	5		27	18	9	5				
	6%	1331	1166	928	1142	25	19	6	3		25	19	6	3				
With HRB E3 (P)	2%	COLLAPSE				33	21	12	6		33	21	12	6				
	4%	840	265	COLLAPSED	368	27	17	10	5		27	17	10	5				
	6%	1243	1309	403	1276	26	19	7	3		26	19	7	3				
With CEM I	2%	COLLAPSED				32	20	12	6		32	20	12	6				
	4%	729	718	801	749	27	19	8	4		27	19	8	4				
	6%	1376	1376	740	1376	25	20	5	3		25	20	5	3				
SAMPLE No. 3																		
With HRB E3 (L)	2%	COLLAPSED				33	19	14	6		33	19	14	6				
	4%	331	1099	1166	1133	28	18	10	5		28	18	10	5				
	6%	1436	1144	249	1290	25	18	7	3		25	18	7	3				
With HRB E3 (P)	2%	COLLAPSED				32	19	13	6		32	19	13	6				
	4%	635	702	779	705	28	19	9	5		28	19	9	5				
	6%	967	1033	751	1000	25	18	7	3		25	18	7	3				
With CEM I	2%	COLLAPSED				29	18	11	6		29	18	11	6				
	4%	807	912	856	858	28	20	8	4		28	20	8	4				
	6%	1204	1354	1315	1291	24	18	6	3		24	18	6	3				

SUMMARY SHEET
Tests on Mutaho Gravel

Sample reference	Atterberg Limits LL (%)	PL (%)	PI (%)	LS (%)	PM	Particle size distribution (%) Percentage passing sieve size (mm) 20	2	0.425	0.075	Grading Modulus GM	AASHTO Class	Organic Content (%)	Compaction T 180 MDD (kg/m³)	OMC (%)	CBR at 100% MDD (%)	Swell (%)	ICL (%)
Before Stabilization																	
SAMPLE No. 1	51	27	24	12	240	100	31	10	5	2.5	A-2-7	0.30	2095	8.5	29(31)	0.2	0.5
SAMPLE No. 2	53	31	22	11	440	86	33	20	15	2.3	A-2-7	0.90	2092	9	30(38)	0.2	0.5
SAMPLE No. 3	53	31	22	11	440	85	33	20	15	2.3	A-2-7	1.24	2090	8.8	33(37)	0.2	0.5

After Stabilization

		UNCONFINED COMPRESSION (7DC + 7DS) MPa	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	LS (%)
SAMPLE No. 1						
With HRB E3 (L)	2%	COLLAPSE	41	26	15	7
	4%	696	39	29	10	5
	6%	464	36	30	6	3
With HRB E3 (P)	2%	199	40	27	13	8
	4%	444	39	29	10	5
	6%	691	36	30	6	3
With CEM I	2%	243	40	27	13	8
	4%	801	37	28	9	5
	6%	1144	35	28	7	3
SAMPLE No. 2						
With HRB E3 (L)	2%	COLLAPSE	42	28	14	8
	4%	497	39	28	11	6
	6%	928	37	28	9	5
With HRB E3 (P)	2%	138	42	30	12	6
	4%	390	39	28	11	6
	6%	1050	37	29	8	4
With CEM I	2%	541	42	30	12	6
	4%	646	39	31	8	4
	6%	1193	35	29	6	3
SAMPLE No. 3						
With HRB E3 (L)	2%	448	41	28	13	7
	4%	116	38	28	10	6
	6%	972	36	29	7	4
With HRB E3 (P)	2%	199	41	29	12	7
	4%	486	38	29	9	5
	6%	1127	36	29	7	4
With CEM I	2%	619	41	29	12	7
	4%	779	38	30	8	4
	6%	1315	34	29	5	2

SUMMARY SHEET
Tests on Masyenze Gravel

Sample reference		Atterberg Limits LL (%)	PL (%)	PI (%)	LS (%)	PM	Particle size distribution (%) Percentage passing sieve size (mm) 20	2	0.425	0.075	Grading Modulus GM	AASHTO Class	Organic Content (%)	Compaction T 180 MDD (kg/m^3)	OMC (%)	CBR at 100% MDD (%)	Swell (%)	ICL (%)
Before Stabilization																		
SAMPLE No. 1		33	24	9	4	171	85	32	19	14	2.4	A-2-4	1.54	1990	13.4	40(46)	0.2	0.4
SAMPLE No. 2		30	22	8	5	80	100	30	10	5	2.6	A-2-4	1.24	1992	13.5	42(47)	0.2	0.4
SAMPLE No. 3		29	22	7	4	70	100	31	10	5	2.5	A-2-4	0.90	1990	13.6	40(46)	0.2	0.4
After Stabilization																		
SAMPLE No. 1																		
		UNCONFINED COMPRESSION (7DC + 7DS)				**ATTERBERG LIMITS**												
			MPa			LL (%)	PL (%)	PI (%)	LS (%)									
With HRB E3 (L)	2%		856			26	20	6	4									
	4%		1254			24	NON-PLASTIC											
	6%		3591			22	NON-PLASTIC											
With HRB E3 (P)	2%		646			26	20	6	3									
	4%		1293			24	NON-PLASTIC											
	6%		3757			23	NON-PLASTIC											
With CEM I	2%		983			27	22	5	3									
	4%		3315			24	NON-PLASTIC											
	6%		5249			21	NON-PLASTIC											
SAMPLE No. 2																		
With HRB E3 (L)	2%		729			27	21	6	4									
	4%		611			24	NON-PLASTIC											
	6%		2762			21	NON-PLASTIC											
With HRB E3 (P)	2%		309			26	20	6	3									
	4%		956			24	NON-PLASTIC											
	6%		1359			22	NON-PLASTIC											
With CEM I	2%		696			28	22	6	3									
	4%		1315			25	NON-PLASTIC											
	6%		4420			22	NON-PLASTIC											
SAMPLE No. 3																		
With HRB E3 (L)	2%		238			28	21	7	4									
	4%		1392			26	NON-PLASTIC											
	6%		3204			24	NON-PLASTIC											
With HRB E3 (P)	2%		657			27	21	6	4									
	4%		1138			25	NON-PLASTIC											
	6%		2486			22	NON-PLASTIC											
With CEM I	2%		967			27	21	6	3									
	4%		1657			25	NON-PLASTIC											
	6%		5249			23	NON-PLASTIC											

APPENDIX II : SAMPLE OF LAFARGE HYDRAULIC ROAD BINDERS MANUFACTURED AND USED IN OTHER COUNTRIES

Country	**HRB Standards**	**Name**	**Applicable rules**
Austria	ON EN 13282	HRB 22,5E HRB 32,5E	ON EN 14227/ON 14227-13 RVS 08.17.01/RVS 11.02.40
Czech Republic	CZ EN 13282		CSN EN 14227-5 CSN 736124
Germany	DIN 18506	Lafarge SOL 50 Lafarge SOL 70 HRB 32,5E HRB 12,5E	DIN EN 14227-5/ DIN 14227-13 ZTV Beton-Stb
Poland	No specified standard		PN EN 14227-5/ PN 14227-13
Romania	SR EN 13282	*Soilmix* HRB 12,5 *Roadmix* HRB 22,5E *Roadmix Plus* HRB 32,5 E	SP EN 1 4227-5/ SR 14227-13
Russia	No specified standards		GOST 26633-91; GOST 12801-98 SNIP (Construction norm and rules) "The bridge and pipes"
France	NF P 15-108	ROLAC PI ROLAC 645 ROLAC 445 ROLAC 425	
USA & CANADA		Terracem Joppa-Exshaw Terracem Edmonton	