Appendix 2.4 Road Length by Class & Organisation of Road Maintenance

Nation area Data

Nation	Area	583,000 Km2
	Road density	0.11 km/km2
	Population (1999)	30,520,000 habits
	Length per capita	0.0021 km/person

1995

	AC	BS	Gravel	Earth	Total	%
A	2,653.0	0.0	716.9	241.0	3,610.9	5.6%
B	0.0	1,304.4	842.3	524.2	2,670.9	4.2%
C	0.0	2,561.7	3,633.6	1,835.3	8,030.6	12.6%
D	0.0	1,183.8	6,570.4	3,584.6	11,338.8	17.7%
E	0.0	749.3	7,651.2	18,670.3	27,070.8	42.3%
Sub-Total	**2653.0**	**5799.2**	**19414.4**	**24855.4**	**52,722**	**82.4%**
	5%	11%	37%	47%	100%	
SPR	0.0	219.5	8,487.3	2,513.1	11,219.9	17.5%
Total	**2,653.0**	**6,018.7**	**27,901.7**	**27,368.5**	**63,941.9**	100%
%	4%	9.4%	43.6%	42.8%	100%	

Bridge na
Box Culvert na

Study area Data

Study	Area	16,184 Km2
Western	Road density	0.50 km/km2
(Busia/Teso)	Population (1999)	5,809,069 habits
Naynza	Length per capita	0.0014 km/person
(all districts)		

	AC	BS	Gravel	Earth	Total	%
A	225.2	0.0	0.0	0.0	225.2	2.8%
B	0.0	179.9	0.0	0.0	179.9	2.2%
C	10.0	372.1	643.6	14.2	1,039.9	12.9%
D	0.0	16.9	858.9	337.4	1,213.2	15.0%
E	0.0	3.0	1,242.8	1,668.2	2,914.0	36.1%
Sub-Total	**235.2**	**571.9**	**2745.3**	**2019.8**	**5,572**	**69.0%**
	4.2%	10.3%	49.3%	36.2%	100%	
SPR	0.0	14.2	1,209.9	1,281.6	2,505.7	31.0%
Total	**235.2**	**586.1**	**3,955.2**	**3,301.4**	**8,077.9**	100%
%	2.9%	7.3%	49.0%	40.9%	100%	

Bridge na
Box Culvert na

Nyanza Province Road Data

12 Districts	Area	14,395 Km2
	Road density	0.51 km/km2
	Population(1999)	5,260,291 habits
	Length per capita	0.0014 km/person

	AC	BS	Gravel	Earth	Total	%
A	210.1	0.0	0.0	0.0	210.1	2.9%
B	0.0	152.9	0.0	0.0	152.9	2.1%
C	10.0	372.1	478.2	14.2	874.5	12.0%
D	0.0	16.9	776.0	278.1	1,071.0	14.7%
E	0.0	3.0	1,112.5	1,575.1	2,690.6	37.0%
Sub-Total	**220.1**	**544.9**	**2366.7**	**1867.4**	**4,999**	**68.7%**
	4.4%	10.9%	47.3%	37.4%	100%	
SPR	0.0	14.2	987.5	1,280.8	2,282.5	31.3%
Total	**220.1**	**559.1**	**3,354.2**	**3,148.2**	**7,281.6**	100%
%	3.0%	7.7%	46.1%	43.2%	100%	

Bridge	na
Box Culvert	na

Western Province Data

Busia	Area	1,789.0 Km2
Teso	Road density	0.45 km/km2
	Population(1999)	548,778.0 habits
	Length per capita	0.0015 km/person

	AC	BS	Gravel	Earth	Total	%
A	15.1	0.0	0.0	0.0	15.1	1.9%
B	0.0	27.0	0.0	0.0	27.0	3.4%
C	0.0	0.0	165.4	0.0	165.4	20.8%
D	0.0	0.0	82.9	59.3	142.2	17.9%
E	0.0	0.0	130.3	93.1	223.4	28.1%
Sub-Total	**15.1**	**27.0**	**378.6**	**152.4**	**573.1**	**72%**
	3%	5%	66%	27%	100%	
SPR	0.0	0.0	222.4	0.8	223.2	28.0%
Total	**15.1**	**27.0**	**601.0**	**153.2**	**796.3**	100%
%	2%	3.4%	75.5%	19.2%	100%	

Bridge	47
Box Culvert	14

District Data

Nyanza Siaya

Area	1,546 Km2
Road density	0.52 km/km2
Population	595,220 habits
Length per capita	0.0014 km/person

	AC	BS	Gravel	Earth	Total	%
A	0	0	0	0	0	0%
B	0	49.5	0	0	49.5	6.1%
C	0	41.4	83.1	0	124.5	15.5%
D	0	0	181.5	0	181.5	22.5%
E	0	0	0	343.4	343.4	42.7%
Sub-Total	**0**	**90.9**	**264.6**	**343.4**	**698.9**	**86.8%**
	0%	13.0%	37.9%	49.1%	100%	
SPR	0	0	106.2	0	106.2	13.2%
Total	**0**	**90.9**	**370.8**	**343.4**	**805.1**	100%
%	0%	11.3%	46.1%	42.7%	100%	

Bridge	18
Box Culvert	19

Source: DWO Siaya/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)

Nyanza **Bond** estimate

Area	972 Km2
Road density	0.53 km/km2
Population (1999)	270,526 habits
Length per capita	0.0019 km/person estimate

	AC	BS	Gravel	Earth	Total	%
A	0.0	0.0	0.0	0.0	0.0	0.0%
B	0.0	0.0	0.0	0.0	0.0	0.0%
C	0.0	52.0	52.2	0.0	104.2	20.2%
D	0.0	0.0	6.3	18.0	24.3	4.7%
E	0.0	1.0	270.0	18.7	289.7	56.2%
Sub-Total	**0.0**	**53.0**	**328.5**	**36.7**	**418.2**	**81.1%**
	0.0%	12.7%	78.6%	8.8%	100%	
SPR	0.0	3.5	76.7	17.0	97.2	18.9%
Total	**0.0**	**56.5**	**405.2**	**53.7**	**515.4**	100%
%	0.0%	11.0%	78.6%	10.4%	100%	

Bridge	18
Box Culvert	19

Source: DWO Bondo/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)

Nyanza **Kisumu/Nyando** estimate

Area	2,250 Km2
Road density	0.74 km/km2
Population (1999)	928,320 habits
Length per capita	0.0018 km/person

	AC	BS	Gravel	Earth	Total	%
A	68.1	0	0	0	68.1	4.1%
B	0	55.2	0	0	55.2	3.3%
C	0	162.7	7.9	0	170.6	10.3%
D	0	12.9	85.2	50.0	148.1	9.0%
E	0	0	254.0	150.1	404.1	24.4%
Sub-Total	**68.1**	**230.8**	**347.1**	**200.1**	**846.1**	**51.1%**
	8.0%	27.3%	41.0%	23.6%	100.0%	
SPR	0	0	200.1	607.9	808.0	48.8%
Total	**68.1**	**230.8**	**547.2**	**808.0**	**1,654.1**	100%
%	4.1%	14.0%	33.1%	48.8%	100%	

Bridge	na
Box Culvert	na

Source: DWO Kisumu/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)

Nyanza **Rachuonyo**

Area	931 Km2
Road density	0.51 km/km2
Population (1999)	313,870 habits
Length per capita	0.0015 km/person

	AC	BS	Gravel	Earth	Total	%
A	42.0	0.0	0.0	0.0	42.0	8.9%
B	0.0	0.0	0.0	0.0	0.0	0.0%
C	10.0	0.0	51.2	4.2	65.4	13.9%
D	0.0	0.0	89.1	14.1	103.2	21.9%
E	0.0	0.0	33.8	42.3	76.1	16.2%
Sub-Total	**52.0**	**0.0**	**174.1**	**60.6**	**286.7**	**60.9%**
	18%	0.0%	60.7%	21.1%	100%	
SPR	0.0	0.0	44.1	140.2	184.3	39.1%
Total	**52.0**	**0.0**	**218.2**	**200.8**	**471.0**	100%
%	11%	0.0%	46.3%	42.6%	100%	

Bridge	20
Box Culvert	7

Source: DWO Rachuonyo/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)
Road Lengths are adjusted by Table 164 of old Homa Bay Distric
Statistics of the above by the Study Team

Nyanza **Homa Bay**

Area	1,126 Km2
Road density	0.44 km/km2
Population (1999)	293,676 habits
Length per capita	0.0017 km/person

	AC	BS	Gravel	Earth	Total	%
A	0	0	0	0	0	0.0%
B	0	0	0	0	0	0.0%
C	0	57.5	47.0	0	104.5	21.1%
D	0	0	80.5	10.5	91	18.4%
E	0	0	84.6	106.0	190.6	38.4%
Sub-Total	**0**	**57.5**	**212.1**	**116.5**	**386.1**	**77.9%**
	0%	14.9%	54.9%	30.2%	100%	
SPR	0	0	98.9	10.9	109.8	22.1%
Total	**0**	**57.5**	**311.0**	**127.4**	**495.9**	
%	0%	11.6%	62.7%	25.7%	100%	178%

Bridge	7
Box Culvert	10

Source: DWO Rachuonyo/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)
Road Lengths are adjusted by Table 164 of old Homa Bay Distric
Statistics of the above by the Study Team

Nyanza **Suba**

Area	1,048 Km2
Road density	0.34 km/km2
Population (1999)	169,444 habits
Length per capita	0.0021 km/person

	AC	BS	Gravel	Earth	Total	%
A	0.0	0.0	0.0	0.0	0.0	0.0%
B	0.0	0.0	0.0	0.0	0.0	0.0%
C	0.0	0.0	43.0	0.0	43.0	12.2%
D	0.0	0.0	14.0	50.0	64.0	18.2%
E	0.0	0.0	0.0	245.0	245.0	69.6%
Sub-Total	**0.0**	**0.0**	**57.0**	**295.0**	**352.0**	**100.0%**
	0.0%	0.0%	16.2%	83.8%	100%	
SPR	0	0	0	0	0	0.0%
Total	**0.0**	**0.0**	**57.0**	**295.0**	**352.0**	100%
%	0.0%	0.0%	16.2%	83.8%	100%	

Bridge	1
Box Culvert	3

Source: DWO Suba/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)
Road Lengths are adjusted by Table 164 of old Homa Bay Distric
Statistics of the above by the Study Team

Nyanza Gucha

Area	657	Km2
Road density	0.77	km/km2
Population(1999)	460,531	
Length per capita	0.0011	km/person

	AC	BS	Gravel	Earth	Total	%
A	0.0	0.0	0.0	0.0	0.0	0.0%
B	0.0	0.0	0.0	0.0	0.0	0.0%
C	0.0	31.0	19.8	10.0	60.8	12.0%
D	0.0	0.0	0.0	87.0	87.0	17.1%
E	0.0	0.0	0.0	175.8	175.8	34.7%
Sub-Total	**0.0**	**31.0**	**19.8**	**272.8**	**323.6**	**63.8%**
	0.0%	9.6%	6.1%	84.3%	100%	
SPR	0	0	0	183.7	183.7	36.2%
Total	**0.0**	**31.0**	**19.8**	**456.5**	**507.3**	100%
%	0.0%	6.1%	3.9%	90.0%	100%	

Bridge	22
Box Culvert	11

Source: DWO Gucha/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)
Road Lengths are adjusted by Table 164 of old Kisii Distric
Statistics of the above by the Study Team

Nyanza Nyamira

Area	879	Km2
Road density	0.73	km/km2
Population(1999)	621,315	habits
Length per capita	0.0010	km/person

	AC	BS	Gravel	Earth	Total	%
A	0.0	0.0	0.0	0.0	0.0	0.0%
B	0.0	18.0	0.0	0.0	18.0	2.8%
C	0.0	0.0	88.7	0.0	88.7	13.9%
D	0.0	0.0	136.9	6.9	143.8	22.5%
E	0.0	2.0	57.7	154.8	214.5	33.5%
Sub-Total	**0.0**	**20.0**	**283.3**	**161.7**	**465.0**	**72.7%**
	0%	4.3%	60.9%	34.8%	100%	
SPR	0.0	2.0	123.3	49.6	174.9	27.3%
Total	**0**	**22.0**	**406.6**	**211.3**	**639.9**	100%
%	0%	3.4%	63.5%	33.0%	100%	

Bridge	7
Box Culvert	10

Source: DWO Nyamira/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)

Nyanza Kisii estimated

Area	645	Km2
Road density	0.87	km/km2
Population(1999)	516,472	habits
Length per capita	0.0011	km/person

	AC	BS	Gravel	Earth	Total	%
A	31.0	0.0	0.0	0.0	31.0	5.6%
B	0.0	30.2	0.0	0.0	30.2	5.4%
C	0.0	11.0	13.2	0.0	24.2	4.3%
D	0.0	0.0	28.6	41.6	70.2	12.6%
E	0.0	0.0	165.4	41.7	207.1	37.1%
Sub-Total	**31.0**	**41.2**	**207.2**	**83.3**	**362.7**	**65.0%**
	8.5%	11.4%	57.1%	23.0%	100%	
SPR	0.0	2.0	171.9	21.6	195.5	35.0%
Total	**31.0**	**43.2**	**379.1**	**104.9**	**558.2**	100%
%	5.6%	7.7%	67.9%	18.8%	100%	

Bridge	7
Box Culvert	10

Source: DWO Kisii/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)
Road Lengths are adjusted by Table 164 of old Kisii Distric
Statistics of the above by the Study Team

Nyanza **Migori**

Area	2,505	Km2
Road density	0.40	km/km2
Population(1999)	565,033	habits
Length per capita	0.0018	km/person

	AC	BS	Gravel	Earth	Total	%
A	53.0	0.0	0.0	0.0	53.0	5.3%
B	0.0	0.0	0.0	0.0	0.0	0.0%
C	0.0	16.5	52.1	0.0	68.6	6.8%
D	0.0	4.0	124.4	0.0	128.4	12.8%
E	0.0	0.0	205.0	199.3	404.3	40.3%
Sub-Total	**53.0**	**20.5**	**381.5**	**199.3**	**654.3**	**65.2%**
	8%	3.1%	58.3%	30.5%	100%	
SPR	0.0	6.7	141.3	199.8	347.8	34.7%
Total	**53.0**	**27.2**	**522.8**	**399.1**	**1,002.1**	100%
%	5%	2.7%	52.2%	39.8%	100%	

Bridge	9
Box Culvert	8

Source: DWO Migori/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)

Nyanza **Kuria**

Area 574 Km2
Road density 0.49 km/km2
Population (1999) 156,737 habits
Length per capita 0.0018 person/km

	AC	BS	Gravel	Earth	Total	%
A	16.0	0.0	0.0	0.0	16.0	5.7%
B	0.0	0.0	0.0	0.0	0.0	0.0%
C	0.0	0.0	20.0	0.0	20.0	7.1%
D	0.0	0.0	29.5	0.0	29.5	10.5%
E	0.0	0.0	42.0	98.0	140.0	49.9%
Sub-Total	**16.0**	**0.0**	**91.5**	**98.0**	**205.5**	**73.2%**
	7.8%	0.0%	44.5%	47.7%	100%	
SPR	0.0	0.0	25.0	50.1	75.1	26.8%
Total	**16.0**	**0.0**	**116.5**	**148.1**	**280.6**	100%
%	5.7%	0.0%	41.5%	52.8%	100%	

Bridge 22
Box Culvert 11

Source: DWO Kuria/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)

Western **Busia**

Area 1,262 Km2
Road density 0.43 km/km2
Population (1999) 369,147 habits
Length per capita 0.0015 km/person

	AC	BS	Gravel	Earth	Total	%
A	0.0	0.0	0.0	0.0	0.0	0.0%
B	0.0	27.0	0.0	0.0	27.0	5.0%
C	0.0	0.0	123.3	0.0	123.3	22.8%
D	0.0	0.0	48.3	38.2	86.5	16.0%
E	0.0	0.0	81.0	80.9	161.9	29.9%
Sub-Total	**0.0**	**27.0**	**252.6**	**119.1**	**398.7**	**73.7%**
	0.0%	6.8%	63.4%	29.9%	100%	
SPR	0.0	0.0	141.3	0.8	142.1	26.3%
Total	**0.0**	**27.0**	**393.9**	**119.9**	**540.8**	100%
%	0.0%	5.0%	72.8%	22.2%	100%	

Bridge 22
Box Culvert 11

Source: DWO Busia/Answer of Questionnaries(1999).
MOPWH Schedule of Callasifeid Road (1995)

Western Teso

Area	527 Km2
Road density	0.48 km/km2
Population (1999)	179,631 habits
Length per capita	0.0014 km/person

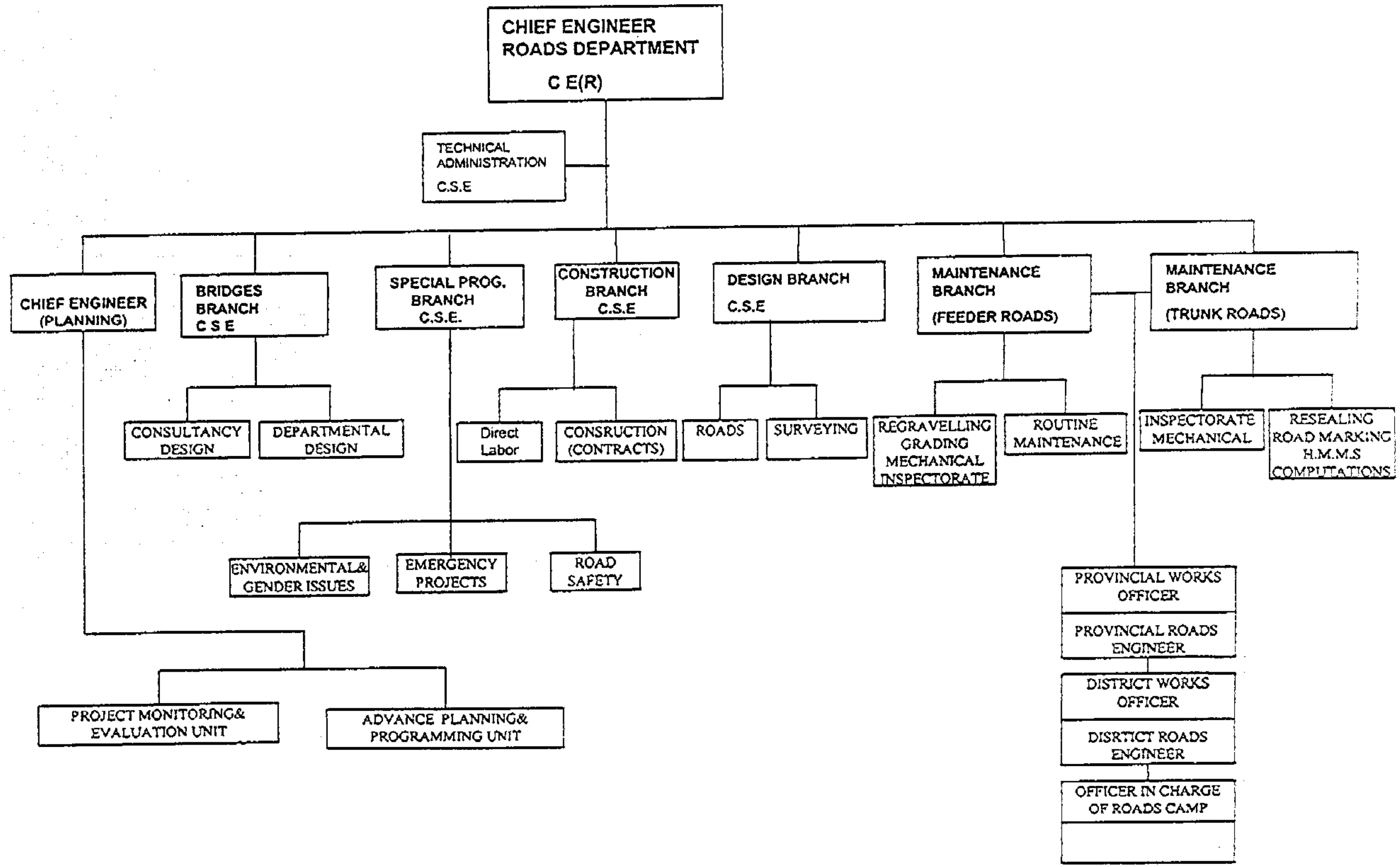
	AC	BS	Gravel	Earth	Total	%
A	15.1	0.0	0.0	0.0	15.1	5.9%
B	0.0	0.0	0.0	0.0	0.0	0.0%
C	0.0	0.0	42.1	0.0	42.1	16.5%
D	0.0	0.0	34.6	21.1	55.7	21.8%
E	0.0	0.0	49.3	12.2	61.5	24.1%
Sub-Total	**15.1**	**0.0**	**126.0**	**33.3**	**174.4**	**68.3%**
	8.7%	0.0%	72.2%	19.1%	100%	
SPR	0.0	0.0	81.1	0.0	81.1	31.7%
Total	**15.1**	**0.0**	**207.1**	**33.3**	**255.5**	100%
%	5.9%	0.0%	81.1%	13.0%	100%	

Bridge	25
Box Culvert	3

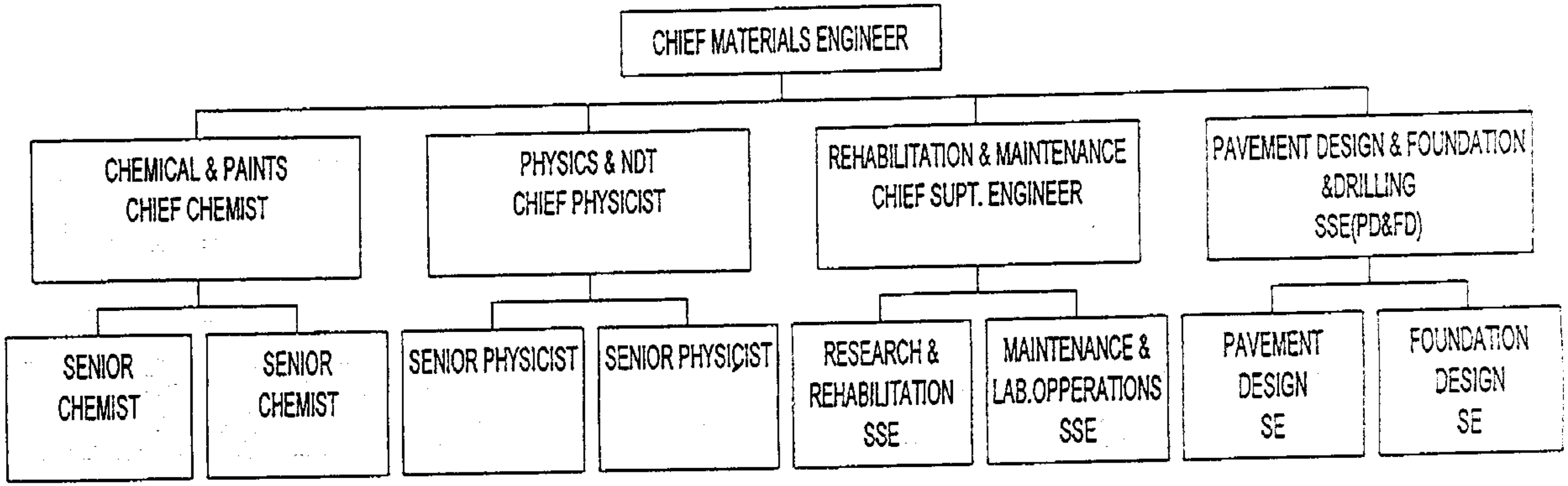
Source: DWO Teso/Answer of Questionnaries(1999)

Appendix 2.5 Organisation of MOR&PW

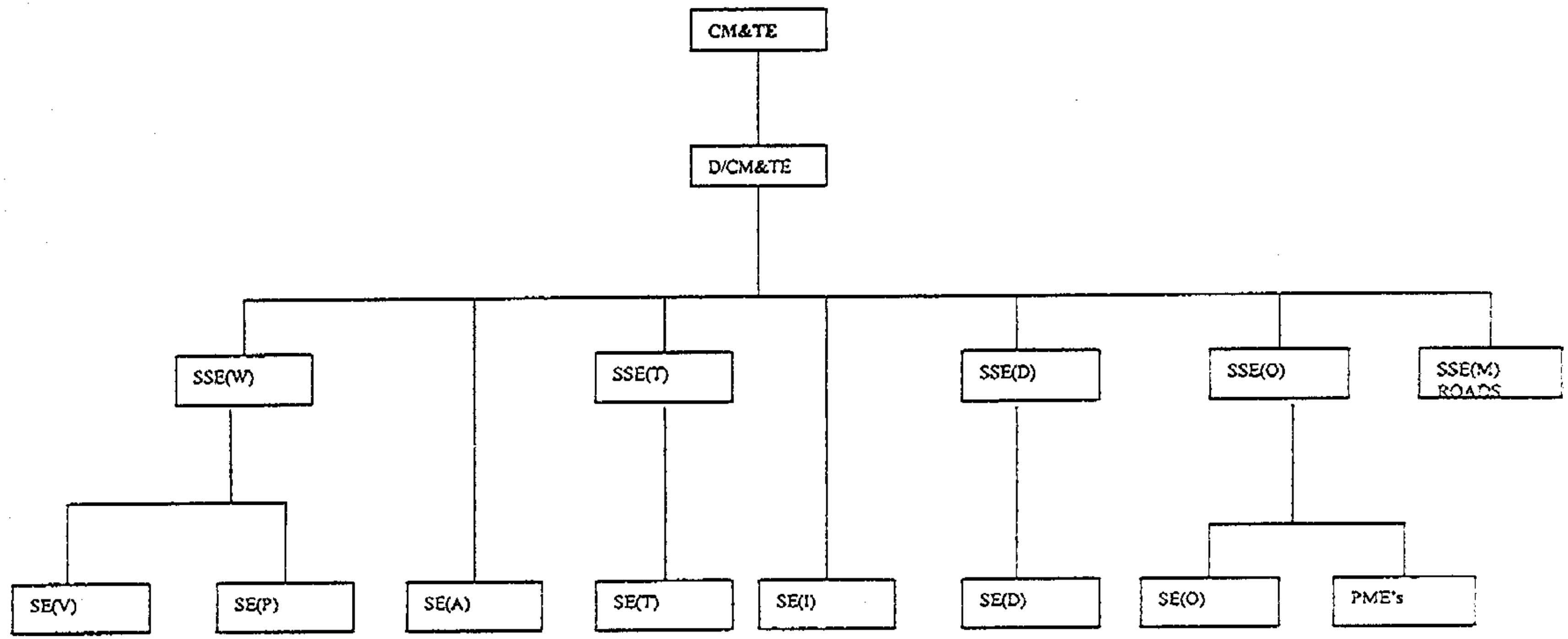
Organisation of Roads Department



Organisation of Material Testing and Research Department



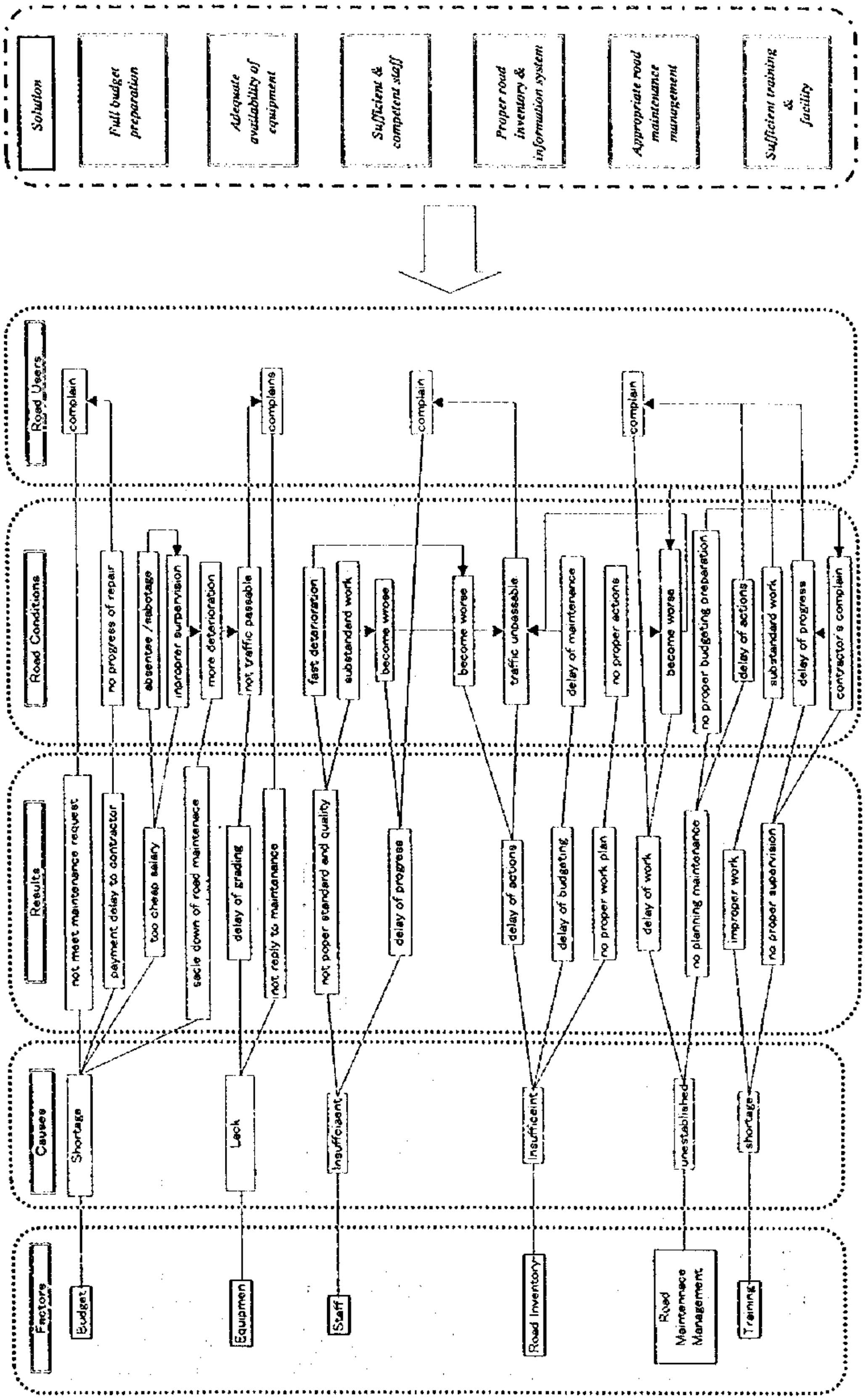
Organisation of Mechanical and Transport Department



KEY

CM&TE	CHIEF MECHANICAL AND TRANSPORT ENGINEER
DCM&TE	DEPUTY CHIEFMECHANICAL AND TRANSPORT ENGINEER
SSE(W)	SENIOR SUPERINTENDING ENGINEER(WORKSHOPS)
SSE(T)	SENIOR SUPERINTENDING ENGINEER(TECHNICAL)
SSE(D)	SENIOR SUPERINTENDING ENGINEER(DEVELOPMENT)
SSE(O)	SENIOR SUPERINTENDING ENGINEER(OPERATIONS)
SSE(M)	SENIOR SUPERINTENDING ENGINEER(MECHANICAL)ROADS
SE(V)	SUPERINTENDING ENGINEER(VEHICLE)
SE(P)	SUERINTENDING ENGINEER(PLANT)
SE(A)	SUPERINTENDING ENGINEER(AXLE LOAD)
SE(T)	SUPERINTENDING ENGINEER(TECHNICAL)
SE(I)	SUPERINTENDING ENGINEER(INSPECTION)
SE(D)	SUPERINTENDING ENGINEER(DEVELOPMENT)
SE(O)	SUPERINTENDING ENGINEER(OPERATIONS)
PME's	PROVINCIAL MECHANICAL ENGINEERS

Appendix 3.1 Analysis Tree of Road Maintenance Problems and Constraints



Analysis Tree of Road Maintenance Problems and Constraints

DWOs Constraints and Opinions of Rural Road Maintenance

MIGORI DISTRICT	**Opinion and program for developing proper rural road maintenance system under your office**			**Constraints for proper road maintenance management, if any**	
1	Labour Based Method	Labour based methods are cheaper but require extensive management input so supervisory resources should be	1	Budget	Always inadequate and can not meet most crucial maintenance requirements. Even routing maintenance workload is rarely
2	Small/ medium contractors	Small-scale/medium contractors should be trained by giving experimental contracts to enhance their capacity to undertake such works.	2	Equipment	Not adequate. The basic machinery like graders, shovels, dozers critically lacking.
3	Training Programme for Road Maintenanc	Supervisory staff should be trained with emphasis on contract supervision and management.	3	Staff	Not adequate. Current staff should be re-trained and motivated. Skills enhancement program necessary.
4	Others	Equipment for road maintenance should be availed or the available ones rehabilitated. An equipment maintenance support should be in place.	4	Maintenance Management System	MOPW&H has set up a management and information system (Standardized) however, this has not been properly utilised for decision making, since it is still new.
		Maintenance management system should be institutionalised.	5	Road Inventory system	Value of inventory system is yet to be realised. The current one does not reflect actual road condition and inputs to resolving bottlenecks or require improvement.
			6	Others	Existing network has not been properly maintained over a long period of time. Most roads now require complete rehabilitation. Procurement systems too lengthy to support timely maintenance response.

table field questinnaires summary

KISII DISTRICT	Opinion and program for developing proper rural road maintenance system under your office			Constraints for proper road maintenance management, if any	
	1 Labour Based Method	N/A		1 Budget	Funds issued by GoK are insufficient to maintain the classified road network effectively. Time of receiving matters in terms of climate conditions wet and dry season.
	2 Small/ medium contractors	N/A		2 Equipment	No enough graders (2 No new required) Komatsu motor graders GD40 type. GD40 wheel loader Komatsu model, tippers and Rollers.
	3 Training Programme for Road Maintenanc	N/A		3 Staff	Plant operators to be enough and properly trained. Casuals issue is an expensive case requires polyreview.
	4 Others	N/A		4 Maintenance Management System	This system is hindered by the interference leaders in terms of funding (they influence funding) whereas professionals knows better which areas requires more attention.
		People living along the classified road should be contracted to maintain them.		5 Road Inventory System	This system should be controlled from the District level instead of headquarters as it is now.
				6 Others	There should be proper scheme of service for the staff attached to maintenance for purpose of motivation.

table field questinnaires summary

BUSIA DISTRICT	Opinion and program for developing proper rural road maintenance system under your office				Constraints for proper road maintenance management, if any	
	1	Labour Based Method	N/A	1	Budget	Inadequate and untimely release of funds.
	2	Small/ medium contractors	N/A	2	Equipment	Availability is low due to frequent breakdowns because of old age and inadequate funds for their repair and maintenance
	3	Training Programme for Road Maintenanc	N/A	3	Staff	Insufficient staff
	4	Others	N/A	4	Maintenance Management System	None
				5	Road Inventory system	Require updating
				6	Others	Lack of sufficient materials and equipment for maintenance of structures and culverts.

table field questinnaires summary

GUCHA DISTRICT	Opinion and program for developing proper rural road maintenance system under your office		Constraints for proper road maintenance management, if any	
1	Labour Based Method	Very economical method, although the works are not done to the required standards.	1 Budget	Funds allocated are insufficient to carry out the maintenance works effectively. More funds are required for effective monitoring and implementation of the maintenance activities
2	Small/ medium contractors	Not yet practiced in this district, but can be tried as a pilot project	2 Equipment	New equipment's required. The ones available are old and repair costs are high and their production is low due to frequent breakage. Supervisory vehicle (4WD) are required for effective monitoring of the maintenance works and their implementation.
3	Training Programme for Road Maintenance	Very necessary to acquire the new skills of Road maintenance.	3 Staff	Supervisory and supportive staff are required, since a large number of the supervisory and supportive staff went on voluntary early retirement and golden handshake retirement.
4	Others	Educate the local communities about the importance of roads in rural areas and involve them in the maintenance works within their locality.	4 Maintenance Management System	For effective maintenance management qualified and experienced personnel are necessary. Also 4WD supervisory vehicles are necessary for proper Implementation and monitoring of the maintenance works.
				- The maintenance crew team needs to be motivated by paying them field allowance or paying them night outs when funds allows (are available). Establish maintenance camp in each division of the District.

table field questinnaires summary

GUCHA District Cont. ...			5	Road Inventory system	Done yearly to update the records of the roads network in the district. But due to lack of supervisory vehicles and Equipment ' s like computers where such information can be stored for future reference, sometimes the road inventory is not carried out, but previous records are used, without updating them.
			6	Others	A well equipped road maintenance office is required for all the above said (Nos. 1,2,3,4 & 5) to be successful, i.e. an office properly furnished and equipped with computers as we're in the computer era and modern technology is important for effective road maintenance.

table field questinnaires summary

SIAYA DISTRICT	Opinion and program for developing proper rural road maintenance system under your office			Constraints for proper road maintenance management, if any	
1	Labour Based Method	Funding levels improvement, Regular training for Road Headmen/Overseers	1	Budget:	This continues to reduce every year and is so inadequate that not much can be done in terms of proper maintenance.
2	Small/ medium contractors	Payment of mobilisation fee to be reinstated, Prompt payment of certificates	2	Equipment:	We have 2 No. old graders, which break-down quite often and as such gives us very low output. The equipment holding is inadequate for the network under our jurisdiction.
3	Training Programme for Road Maintenanc c	Training of small/medium contractors	3	Staff:-	Most experienced Plant Operators and Mechanics, Overseers and Subordinate staff have left the service under the Voluntary Early Retirement Scheme. The Department cannot train staff at the same pace and thus the output is grossly hampered.
4	Others	Privatise all road maintenance activities and encourage small-medium contractors to venture into this sector.	4	Maintenance Management System	There is no defined maintenance management system as currently funding is inadequate, however, there is a policy that roads should be regravelled every five (5) years and be subject to routine maintenance in the interim period i.e. grading twice every year.
			5	Road Inventory System	Provision of Computer would contribute to improve roads Inventory System. Currently Inventory at the District level is not very well co-ordinated. Roads are not inspected as often as should be due to poor funding and this leads to poor inventory of

table field questinnaires summary

			6	Others:	Staff morale is too low due to poor remuneration and lack of working tools and equipment. This should be looked into.
NYAMIRA DISTRICT	**Opinion and program for developing proper rural road maintenance system under your office**			**Constraints for proper road maintenance management, if any**	
1	Labour Based Method	N/A	1	Budget:	Not enough
2	Small/ medium contractors	N/A	2	Equipment:	Not enough
3	Training Programme for Road Maintenanc	N/A	3	Staff:-	Most staff retired through the golden handshake
4	Others	N/A	4	Maintenance Management System	Not fully defined
			5	Road Inventory System	OK
			6	Others:	N/A

table field questinnaires summary

KISUMU DISTRICT	Opinion and program for developing proper rural road maintenance system under your office		Constraints for proper road maintenance management, if any		
1	Labour Based Method	N/A	1	Budget:	Inadequate
2	Small/ medium contractors	A pool of Machinery to be hired by small/medium contractors can be established in the Districts or Provinces.	2	Equipment:	Inadequate
3	Training Programme for Road Maintenanc	Organised seminars for management of contracts and general construction.	3	Staff:-	Adequate
4	Others	N/A	4	Maintenance Management System	Inadequate
			5	Road Inventory System	Inadequate
			6	Others:	None

table field questinnaires summary

BONDO DISTRICT	Opinion and program for developing proper rural road maintenance system under your office		Constraints for proper road maintenance management, if any		
1	Labour Based Method	N/A	1	Budget:	Budgetary constraints
2	Small/ medium contractors	N/A	2	Equipment:	Lack of appropriate equipment, and the ones that are available are old and can hardly work for a day or so without developing mechanical problems.
3	Training Programme for Road Maintenanc	N/A	3	Staff:	Due to voluntary retirement, normal retirement
4	Others	N/A	4	Maintenance Management System	N/A
			5	Road Inventory System	N/A
			6	Others:	N/A

table field questionnaires summary

NYANDO DISTRICT	Opinion and program for developing proper rural road maintenance system under your office			Constraints for proper road Maintenance Management, if any	
1	Labour Based Method	N/A	1	Budget:	Sufficient funds are not issued to cover the workplan
2	Small/ medium contractors	N/A	2	Equipment:	Frequent breakdown of machines and equipment's and non repair in good time makes road maintenance management not to be achieved.
3	Training Programme for Road Maintenanc	N/A	3	Staff:-	Shortage of trained personnel is a hindrance to road maintenance management.
4	Others	N/A	4	Maintenance Management System	Enough funds, equipment, and machines should be available for it to succeed.
			5	Road Inventory System	Proper road inventory records which is done in good time should be enhanced and followed.
			6	Others:	N/A

table field questinnaires summary

TESO DISTRICT	Opinion and program for developing proper rural road maintenance system under your office			Constraints for proper road Maintenance Management, if any	
1	Labour Based Method	N/A	1	Budget:	Lack of adequate funds in relation to yearly work plan requirements
2	Small/ medium contractors	A pool of machinery to be hired by small medium contractors can be established in the districts or provinces.	2	Equipment	Inadequate equipment, old ones available for use
3	Training Programme for Road Maintenanc	Organised seminars for management of contracts and general construction.	3	Staff	Not a major problem since plant operators can be available from neighboring districts or be trained.
4	Others	N/A	4	Maintenance:	Reporting System not clearly understood by field staff on site especially overseers.
			5	Road Inventory System	No Constraints
			6	Others	N/A

table field questinnaires summary

HOMABAY DISTRICT	Opinion and program for developing proper rural road maintenance system under your office			Constraints for proper road Maintenance Management, if any	
1	Labour Based Method	Labour based maintenance system don't seem to work on long terms.	1	Budget:	Too low Budgets and at time complete non availability of funds.
2	Small/ medium contractors	Should be encouraged.	2	Equipment	No Equipment, existing Equipment few and old requires maintenance all the time
3	Training Programme for Road Maintenanc	Ground training (do work)	3	Staff	Adequate staff
4	Others	N/A	4	Maintenance Management System:	OK
			5	Road Inventory System	To overhaul the system with a view of improving it
			6	Others	Timing of funding for maintenance

table field questinnaires summary

SUBA DISTRICT	Opinion and program for developing proper rural road maintenance system under your office			Constraints for proper road Maintenance Management, if any	
1	Labour Based Method	Should be contracted	1	Budget:	The budget allocation is very inadequate. It can only maintain about 10% of the total road network.
2	Small/ medium contractors	Should be given to local contractors.	2	Equipment	Most of the critical road maintenance equipment e.g. graders, Dozers, Shovels tippers rollers and water tankers are missing. The only one grader available is too old and unreliable.
3	Training Programme for Road Maintenanc	Every officer involved in road maintenance should attend refresher course at KIHBT after 4 years.	3	Staff	All the professional and Technical staff is adequate. The shortage is on the road overseers.
4	Others	The morale of officers should be raised through their salaries to that private sector.	4	Maintenance Management System:	The maintenance management system is good but its goal can not be achieved due to lack of the above factors (i) and (ii)
			5	Road Inventory System	Needs to be improved further by computerization of each road inventory and update the same periodically.
			6	Others	Improve on supervision by providing more high vehicles. Also improve on staff emoluments to increase their morale.

table field questinnaires summary

RACHUONYO DISTRICT	Opinion and program for developing proper rural road maintenance system under your office			Constraints for proper road Maintenance Management, if any	
1	Labour Based Method	The Labour based method should be restricted to the feeder roads as a means of creating employment for the local communities for economic development.	1	Budget:	The funding for maintenance activities has been in adequate over the years. Money should be set aside for maintenance to back that which is used for construction
2	Small/ medium contractors	Contractors should be trained and funded and considered for contracts in the districts where they come from, to asses the impact of the program.	2	Equipment	The age, condition and number of our equipment is a big constraint to our effective maintenance capacity there is need to for 2 no graders, 1 shovel, 2 tippers, 1 roller for effective and adequate maintenance.
3	Training Programme for Road Maintenanc e	the road maintenance methodology changed to incorporate new ideas and policies it is very important that the supervisory staff be taken for inservice training to appraise themselves of the same for effective maintenance activities.	3	Staff	With additional of equipment in there should be a corresponding increase of operators/drivers
4	Others	The major roads should be maintained by machine based methods since it is quicker and more effective.	4	Maintenance Management System:	The System is no hindrance to the achievement of our work output as required.
			5	Road Inventory System	The inventory is already done for routine. and periodical maintenance activities.
			6	Others	The Workshops maintenance capacity is a hindrance since we don't have welding machines, battery changers and gas cylinders.

table field questinnaires summary

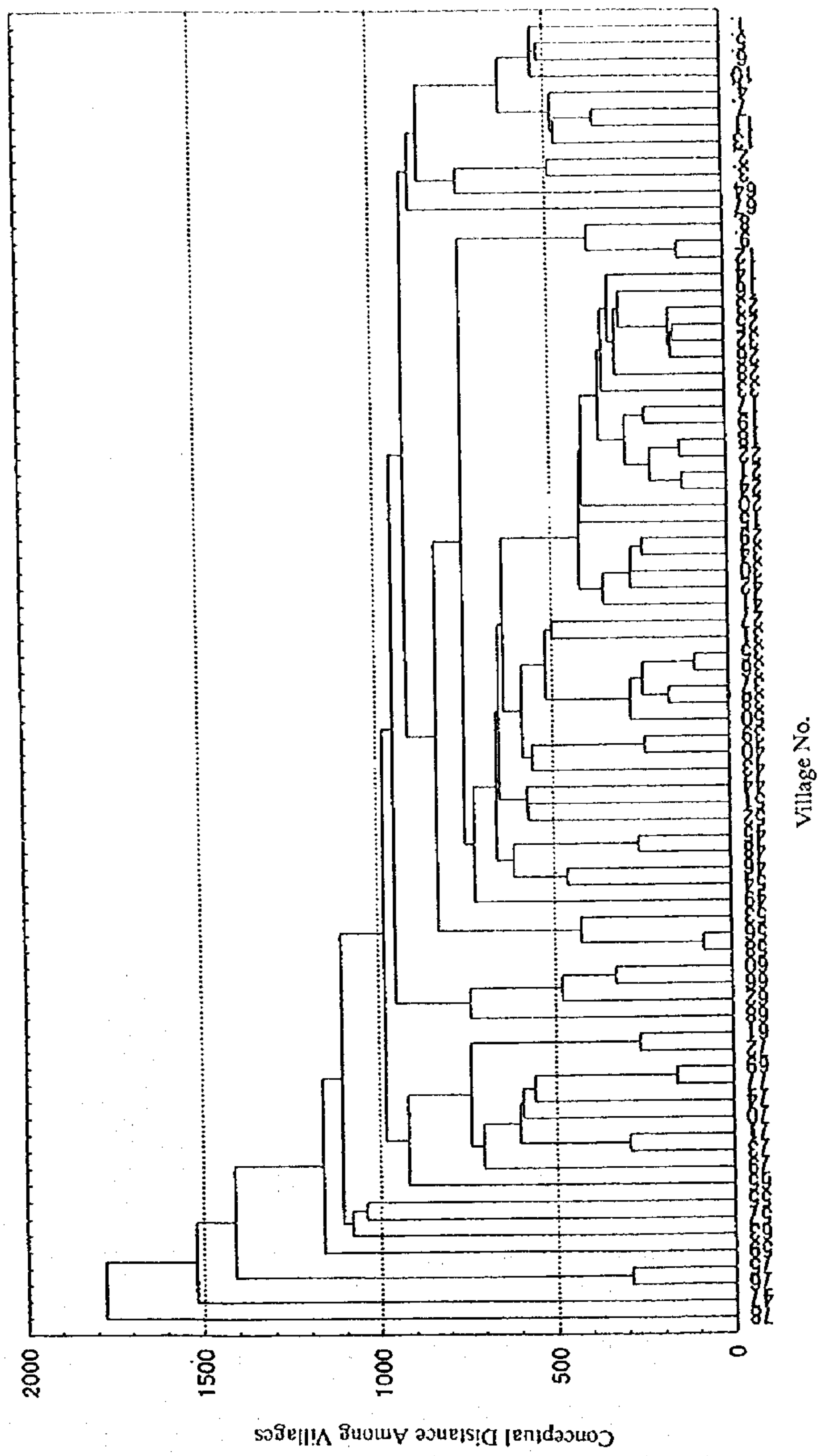
KURIA DISTRICT	Opinion and program for developing proper rural road maintenance system under your office			Constraints for proper road Maintenance Management, if any	
			1	Budget:	Budget allocation usually not adequate for programmed works. Delay in providing funds result in poor implementation and management of works.
1	Labour Based Method	N/A	2	Equipment	Lack of adequate and mechanically sound machinery leads to poor productivity and cost overruns
2	Small/ medium contractors	N/A	3	Staff	Inadequate staffing of skilled personnel results in poor implementation and supervision of works
3	Training Programme for Road Maintenanc	N/A	4	Maintenance Management System:	The recent frequent changes of Management System result in poor reporting of progress and constraints due to inadequate briefings.
4	Others	N/A	5	Road Inventory System	lack of funds to continually update the Road Inventory result in poor forward planning and can result in duplication.
			6	Others	Outdated procurement methods have become a bottleneck in the smooth flow of implementing works.

table field questinnaires summary

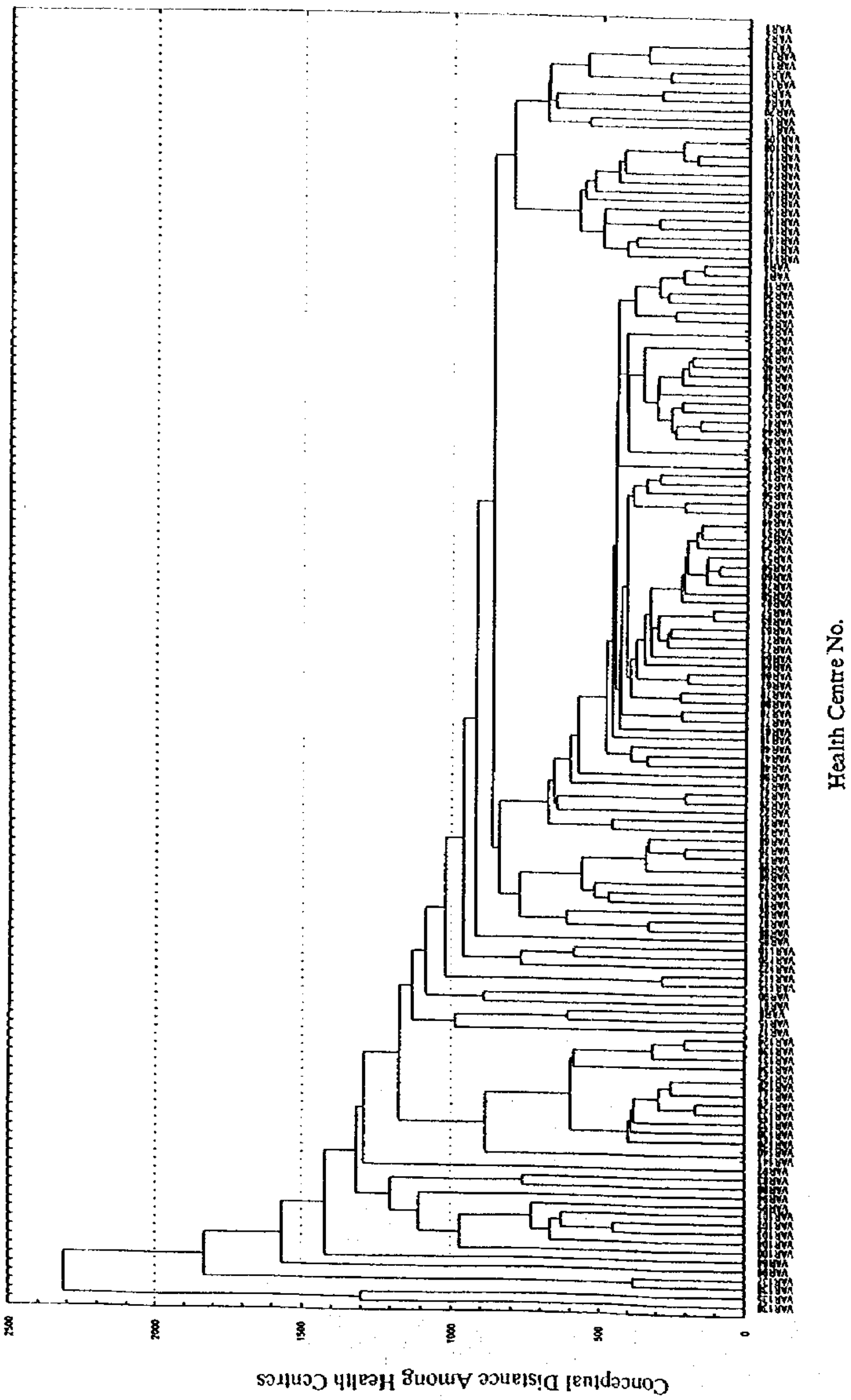
TRAINING NEEDS SUMMARY

NO	COURSE	DISTRICT REQUESTED	DURATION PREFERRED	TARGET STAFF
1	Degree Course	1	3 years	Senior Inspector Roads
2	Road Maintenance Activities	9	6 months – 1 year	All Maintenance Staff
3	Proficiency Course	6	6 months – 1 year	All technical Staff
4	Equipment Maintenance	6	6 months – 1 year	Workshop Staff and Equipment Operators
5	Plant Maintenance	5	6 months – 1 year	Workshop Staff and Plant Operators
6	Computers	3	1- 2 years	Road Engineers, Planners and Clerical Staff
7	New Construction Methods	2	1- 2 years	All technical Staff
8	Management & Supervision	2	1- 2 years	All Management and Supervision Staff
9	Procurement of Construction Materials	1	1- 2 years	Administration, Mechanical Dept., DA
10	Procurement of Construction Equipment	1	1- 2 years	Mechanical Dept., Technical Staff
11	Periodic Refresher Courses	2	6 months – 1 year	All Staff

Appendix 4.1 Cluster Tree



Cluster Tree by Administrative Centres



Cluster Tree by Health Centres

Appendix 5.1 Road Inventory Manual

Appendix 5.1 Road Inventory Form and Inspection Manual

1. Road Inventory Form

The current road inventory has no data and information on road conditions except road pavement type. We prepared a draft form for road conditions survey mainly by visual inspection in Phase I for damage inspection. This form is also used in Phase II for road and pavement conditions inspection. The data obtained can be applied for HDM in Phase III with minor revisions.

In order to establish computerised data base of road conditions, further co-ordination is necessary with other donors.

2. Road Inspection Manual

An inspection manual is proposed how to use the proposed form regarding road inventory on road conditions. The above form is required to be filled out at least once a year in time for preparation of annual maintenance programme, preferably after the rainy season.

The form includes three reporting sections:

Item A – G : applicable to bituminous paved roads

Item H – K: applicable only to gravel and earth roads together with item A and B

Item L – O: side drainage and shoulders

An inspection form will be completed for each one-kilometre section, generally, of road between Km posts installed or other reference points for road link. Where road conditions are uniform and repeated for more than one kilometre, the same form may be used with reference made to the length of segment under inspection, and the total length clearly shown in the description on the top of report form.

The form will be filled in very carefully in order to describe accurately each of the existing conditions and pavement defects at the time of field survey. The survey details given will provide specific road conditions and distress data for road maintenance assessment and intervention levels which are to be used in preparation of the planing maintenance proposed.

3 Method and Definitions for Road Maintenance Inventory

3.1 Survey Method

(1) General

The following items will be filled in on commencement of the field survey

1) Province (name and code number)
2) District (- ditto-)
3) Date (day/ month/ year)
4) Link (name and number)
5) Segment Name (from:......... to.........)
6) Length of Segment (km)
7) Average road width-shoulder / pavement/ shoulder
8) Average Daily Traffic (if possible Passenger Car Unit: PCU)
9) Completed by (name of the person responsible for the field survey)

(2) OECD Catalogue of Road Surface Deficiencies

Before starting the survey, the field crew should become familiar with the description of the items as shown on the report form. Adequate training is required, using proper training materials as illustrated in the typical photographs in order to be able to quickly recognise and record the various conditions as they will appear on the road link or segment being surveyed. In order to coordinate the other donors' efforts, a 'OECD Catalogue of Road Surface Deficiencies' is recommended for use. Source of the following definitions are OECD's and the study team review.

(3) Logistic Support Required

At the start of the survey, the field crew and the DWO should have enough logistic support, such as transportation, field allowance, a computer sytem for data base, in particular sufficient forms to carry out the survey on the assigned road link.

(4) Preliminary Run for Inventory Preparation

It is recommended to use a vehicle for a preliminary run at proper speed, approximately 50kmh or less, in order to survey a link, where main road features and uniformity of pavement condition are identified.

(5) Starting Point

The field crew should start the survey at a kilometer post or a data reference point (DRP) at the beginning of the road link being surveyed and drive slowly towards the next kilometer post or DRP observing the various road conditions.

(6) Ending Point

At the end of the survey segments the field crew will fill in the form for the section by putting marks (v) against the rating number and defect that indicate the average or most predominant condition for each of the survey items listed.

(7) Culvert Inspection

All culverts should be inspected for condition and adequacy, and consideration given to:

a. Structural stability

b. Alignment (location)

c. Out fall conditions

d. Additional culvert

e. Additional culvert requirement

(8) Bridge Inspection

Bridges will normally be subject to a separate survey, and inspection under this road maintenance survey will be limited to bridge decks, drainage, and railings.

For evaluating and costing purposes it will be necessary for the survey crew to estimate the extent of defects found in terms of percentage area or length (as indicated on the form), and to insert % figures in the respective boxes shown.

Visual estimates of size, depth and percent of area will be generally sufficient, unless defects are severe, in which case measurements may be required and special report included.

(9) "None" Box

Where the survey item does not exist or none of the other conditions apply, the field crew should mark (v) the "None" box. For wide road sections separated by a median divider, the form will be filled in for each side of the road pavement.

(10) Completion of Inventory

When the field survey crew have completely filled in the form for the first road section, they should proceed with the survey for the next adjoining segment. The survey crew should continue in this way untill all road sections on the assigned road link have been surveyed and the form filled in.

4. General Definition

(1) Link

A continuous section of road between interconnecting nods of the major road network, often joining major towns or villages. Each link is identified separately by a link number.

(2) Segment

A segment is a part of a link with uniform and similar pavement and drainage conditions. Traffic volume throughout the link will also be of the same level.

(3) Pavement Surface Type:

For the purpose of the rural road maintenance, pavement types are classified into the following categories

a. Bituminous Pavement: Asphalt Concrete (AC)

b. Bituminous Surface Treatment (BST)

c. Gravel and Earth Road

5. Bituminous Paved Road

(1) A: Surface appearance:

The apparent condition of a pavement surface as determined by visual inspection and engineering judgement. The appearance of the surface depends on the size, shape, arrangement, and distribution of aggregate and binder (texture).

1) Roughness:

Vertical deviation from the design shape, occurring at the pavement surface in the longitudinal direction of the road affecting the functional condition of a road pavement. Irregularities in pavement surface also affect rideability of a vehicle.

In Phase III, we propose to introduce equipment measurement for IRI (International Roughness Index) for bituminous roads of Class C at first . Visual inspection will continue for the roads under Class D.

2) Ravelling

Stripping or separation and loss of aggregate from the bituminous surface binder. Separation of bituminous film from aggregates stripping due to water action, chemicals or machine forces.

(2) B: Potholes

Areas of pavement surface which have separated from the base, initially forming a 'shallow' surface pothole. If left unrepaired, the shallow potholes will quickly lead to the damage of the road base forming 'deep' potholes. The form distinguishes between shallow potholes (<10cm deep) and deep potholes (>10cm deep) and requires an estimate of the % pavement area affected within the segment.

(3) C: Depressions:

Localised drop in the level of pavement surface due to base failure or sub base subsidence. Cause may be due to compression or displacement in road bed. Special field engineering investigations are required to determine cause prior to undertaking repairs, and such depressions should be marked by white paint during the maintenance survey inspection.

The form defines three types of depression to be reported:

a. Shallow < 5cm

b. Medium > 10cm

c. Large > 10cm

In each case, the % area should be stated.

(4) D: Cracking

This pavement surface defect can be of three general types:

a. Transverse line across the pavement,

b. Longitudinal line in same direction as wheel tracks and often due to inadequate base thickness,

c. Network cracking --area of interconnected 'alligator' type cracking, usually indicating unstable base, but may be due to deterioration and hardening of asphalt in wearing course.

Type of cracking and likely cause should be stated in the survey inspection notes. Cracking is to be reported and estimated for :

a. Small areas < 20m2

b. Large areas > 20m2

In addition, line cracking due to edge failure and in wheel tracks is also to be recorded separately.

(5) E: Wheel Track Rutting

This is a surface shape defect, more prominent and evident in the outer wheel track, where vehicle wheel loading on the pavement has caused a loading consolidation of the base course or settlement of the foundation layers.

Two types of wheel rutting can be identified:

a. Non structural rutting with displacement of upper pavement layers only.

b. Structural rutting where foundation layers is also disturbed.

For wheel rutting, the survey inspection report should record 'some' or 'continuos', and also provide information in respect of :

a. Percentage (%) of length and average depth of rutting

b. Type of rutting i.e. structural or non-structural.

(6) F: Patches

There are seen as pavement surface repairs and indicate areas where structural repair has been carried out such as potholes and depression repair.

For inspection purposes two categories of patching work are to be recorded:

a. Small patches each less than 10 m2 in area

b. Large patches each more than 10 m2 in area.

Total percentage (%) of area should also be estimated.

(7) G: Rideability

Pavement vehicle riding condition over the segment of road is to be recorded in terms of comfort and safety, under the categories, smooth, rough, or dangerous. It is a form of engineering judgement that gives an additional description of pavement shape.

6. Gravel and Earth Road

(1) H: Soft Spots

Localised areas where the road formation has settled due to unsatable material or poor subsoil conditions. Often occurs in outer wheel track of the road.

Soft spot to be recorded in survey form by percentage (%) are for:

a. Small < 2 m2

b. Large > 2m2

(2) I: Surface Erosion

Gravel roads will normally be provided with an all weather road base/ surface, consisting of gravel, using either natural river gravel or crushed rock.

Earth road has a surface of Maramu (local sub-base material) or no surface treatment made.

(3) J: Wheel Ruts:

There are longitudinal depressions that form in traffic wheel paths due to unstable road material or inadequate base course material. For gravel/earth roads, the ruts are usually aggravated by rainwater collecting in channels. Ruts are to be recorded as:

a. Shallow < 10cm

b. Deep > 10cm

(4) K: Corrugations:

Transverse ridges that develop across gravel roads due to the action of traffic on an unstable pavement where the surface layer over under type pressure. The corrugations form at regular and close intervals (up to 1m) and indicate the need for blading and grading of the surface material.

a. Some (irregular)

b. Continuous

7. Side Drainage and Shoulders

(1) L: Camber for Surface Run-Off

Effectiveness of pavement camber and shoulder grade and level can provide lateral run-off of surface rainwater into the side ditches. The inspection report requires a simple comment: good or poor, relating to road camber, and to shoulder cross fall and level. Where side transverse channels are cut through the shoulders or verges to facilitate effective drainage. This should be noted.

(2) M: Side Ditches

All roads should have side drains or ditches to convey and disperse the local run-off water to protect the shoulders and road edges and to maintain the road pavement in a stable dry condition. In some embankment or hillside locations, drains are not required due to relative levels. Ditch invert levels should be a minimum of 60 cm below pavement level. The ditches should be well graded and free of obstruction.

Ditch condition should be reported in terms of good , poor, or bad, and comments made in respect to defects found. Length of defects should also be included.

(3) N: Culverts:

The term refers to round concrete or metal pipes, and rectangular shape wooden or concrete boxes laid transversely under the road as part of the road drainage system.

Culverts should be structurally sound, and adequate for drainage requirements. The form requires culvert details in terms of conditions, good or blocked (or partially blocked), and also information concerning adequacy. The length of defects is to be includes.

(4) O: Side Shoulders and Banks:

A road shoulder may be defined as side areas adjoining the pavement which can be used by motorised vehicles leaving the pavement for parking or stopping, by non-motorised vehicles or pedestrians for access or passage way.

The shoulder may include part or all of the area between the edge of the pavement and the side drainage ditch, or between the pavement and the top of slope in embankments or between the pavement and bottom (toe) of slope cutting, if no drainage ditch.

The shoulder may be constructed in hard or soft material, and also include grass verges, and when in good condition should be at a satisfactory level and slope from the pavement for safe and easy access and for side drainage purposes.

Shoulder level is an important feature in relation to pavement level, and is required to report in the survey inspection as follows:

a. Shoulder high when > 10cm above pavement edge.

b. Shoulder low when > 10 cm below pavement edge.

It is also necessary to observe side bank slope conditions for cutting and embankments and to give the length with comments on defects.

Road Inventory Form (Draft)

Rural Roads Development Project (JICA)	Road Maintenance Survey & Conditions Report		Date Prepared / /	Total Length km
			1 km Sections	
Province :	Link No.	ADT(Psu/day)	From:	
District :	Road Width		To:	

	Description	Type of Defect		For Comments	Office Use
Bituminous Pavement	A: Surface Appearance	☐ Good Texture ☐ Rough ☐ Rough and ravelling ☐ Break up			(rating Analysis)
	B: Potholes	☐ None ☐ Shallow <10cm ☐ Deep >10cm	% Area		
	C: Depressions	☐ None ☐ Shallow < 5cm ☐ Medium <10cm ☐ Large >10cm	% Area		
	D: Cracking *indicate type*	☐ None ☐ Small areas <20cm2 ☐ Large areas >20cm2	% Area	Line Cracking ☐ Network Crackin; ☐	
	E: Wheel Track Rutting *indicate type*	☐ None ☐ Some (short length) ☐ Continuous	% length	Structural ☐ Non-structural ☐ Edge Failure ☐	
	F: Patches	☐ None ☐ Small <10m2 ☐ Large >10m2	% Area		
	G: Rideability (for comfort & safety)	☐ Smooth ☐ Rough ☐ Dangerous			
Gravel and Earth Surface	H: Soft Spots	☐ None ☐ Some <2m2 ☐ Large >2m2	% Area		
	I: Surface erosion	☐ None ☐ Loss of crown ☐ Edge erosion	% Area		
	J: Wheel Rutting	☐ None ☐ Some (short length) ☐ Continuous	% Length		
	K: Corrugations	☐ None ☐ Some ☐ Continuous	% Area		
PVMT	L: Road Camber	☐ Road Camber : Good ☐ Poor ☐ ☐ No Camber			
Shoulder	M: Side Shoulders and Banks	☐ No Shoulder ☐ Shoulders High >10cm ☐ Bank slips		Shoulder Needed High ☐ Low ☐	
Drainage	N: Culverts	☐ Good ☐ Blocked ☐ Need Repair ☐ Need New	Length(m)		
	O: Side Ditches/Drains	☐ Good ☐ Fair ☐ Poor ☐ No Ditches/Drains			

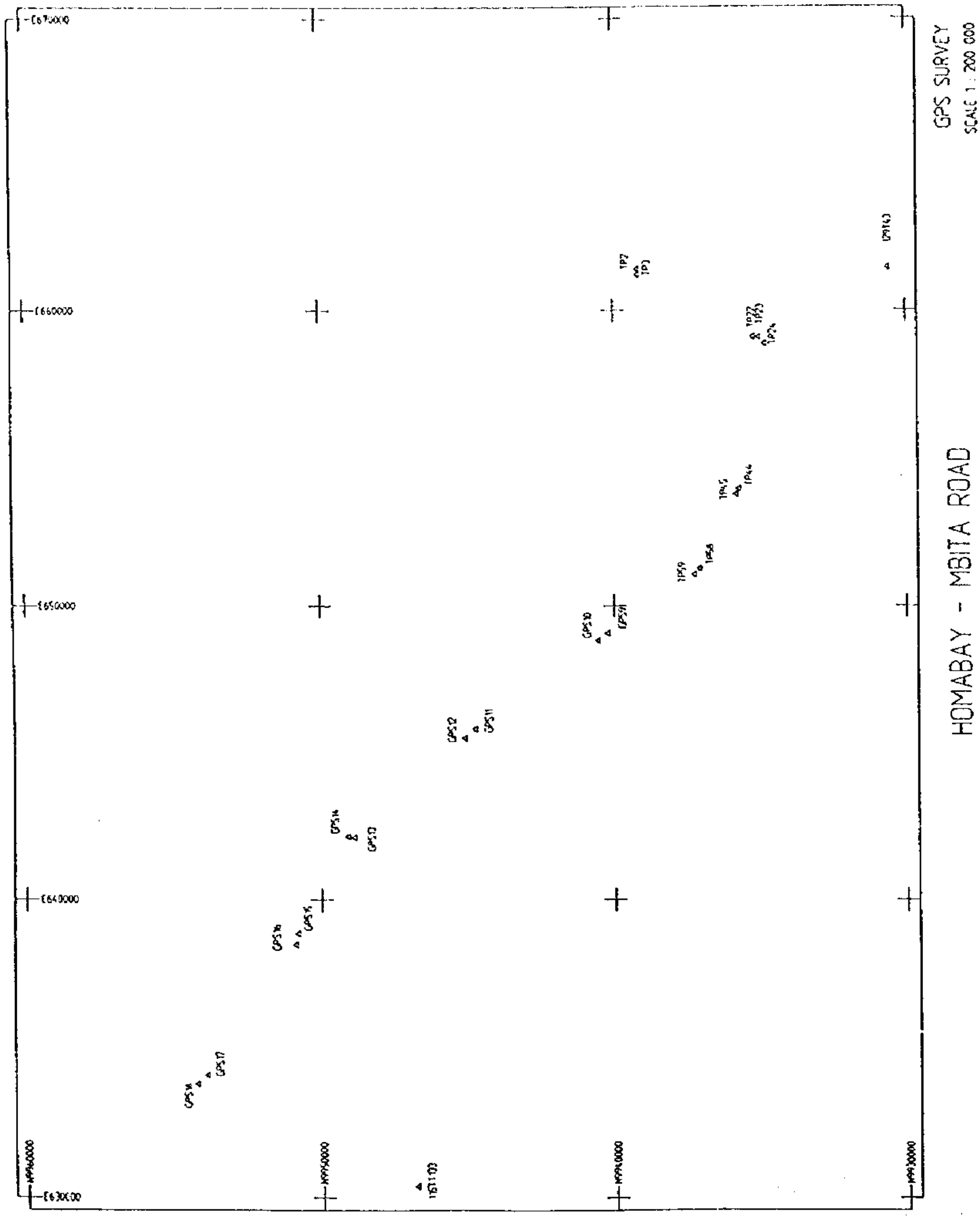
Rating Analysis				Maintenance Work Recommended		
Pavement		Drainage		Pavement	Shoulders	Drainage
Good		Good				
Fair		Fair				
Poor		Poor				
Bad		Bad				

prepared by:

Appendix 7.1 Coordinates of Topographic Survey

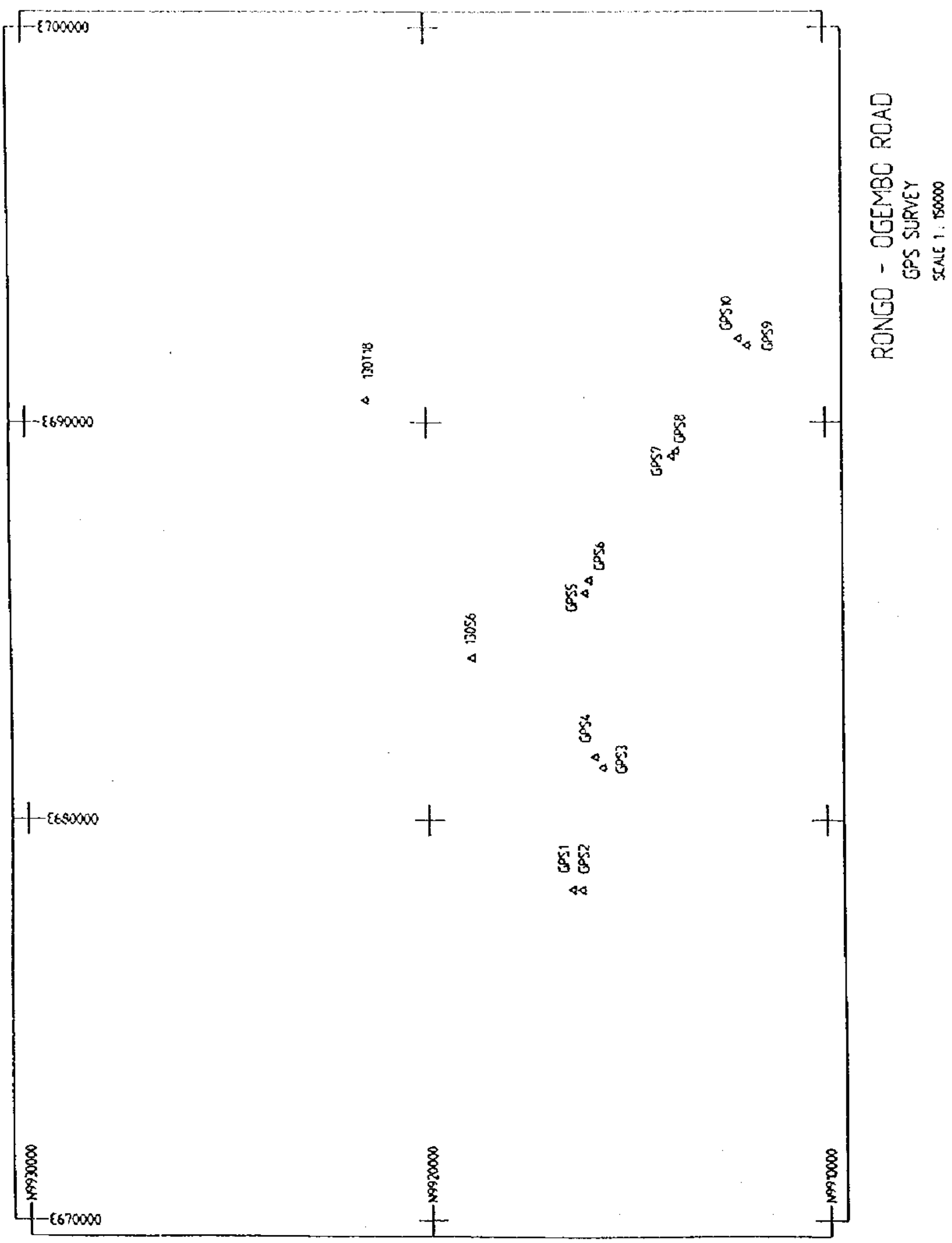
HOMABAY - MBITA

Point Id	X-Coord	Y-Coord	Z-Coord	Point Code
129T43	9930586.140	661445.810	1387.820	72
TP2	9939163.540	661394.660	1241.720	72
TP3	9939140.764	661208.816	1243.528	72
TP23	9935026.216	659070.036	1318.309	72
TP24	9934831.867	658860.964	1322.637	72
TP44	9935747.788	653936.407	1228.561	72
TP45	9935842.294	653750.942	1231.938	72
TP58	9937101.839	651245.701	1293.329	72
.P59	9937284.003	651040.468	1301.839	72
GPS9	9940206.075	649064.743	1239.476	72
GPS10	9940546.173	648823.585	1226.972	72
GPS11	9944732.170	645839.829	1171.676	72
GPS12	9945081.427	645532.730	1167.388	72
GPS13	9948883.780	642120.245	1136.409	72
GPS14	9949097.131	642151.718	1136.349	72
GPS15	9950822.667	638892.021	1169.806	72
GPS16	9950903.302	638531.577	1156.499	72
GPS17	9953908.436	634193.553	1136.494	72
GPS18	9954263.477	633903.470	1141.369	72
TP22	9935238.926	659081.145	1312.675	72
115TT133	9946821.540	630377.820	1255.280	72


GPS SURVEY
SCALE 1 : 200 000
HOMABAY - MBITA ROAD

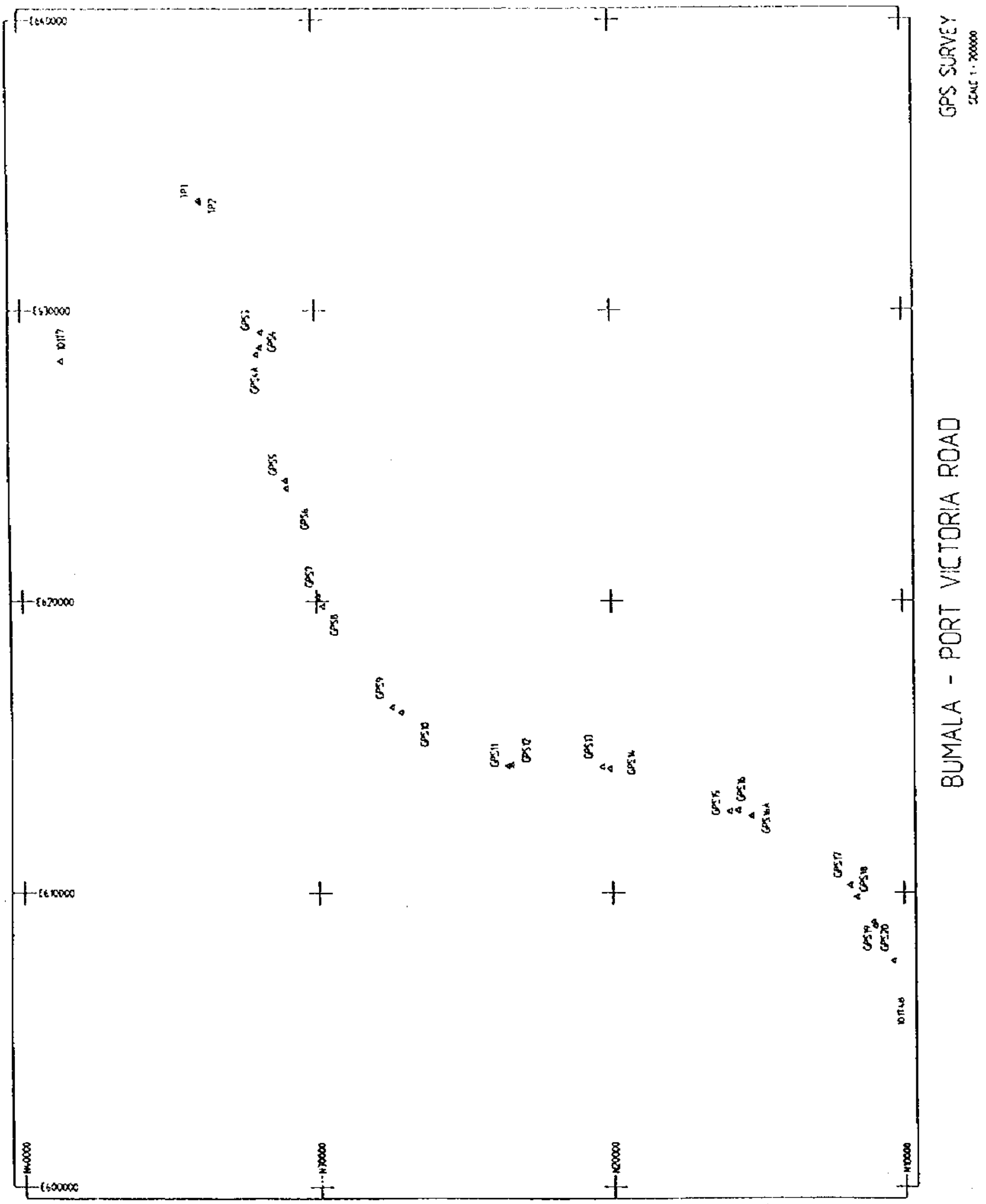
RANGO - OGEMBO

Point Id	X-Coord	Y-Coord	Z-Coord	Point Code
130S6	9918878.760	684076.320	1777.440	72
GPS1	9916404.444	678251.355	1475.750	72
GPS2	9916161.355	678244.418	1477.886	72
GPS3	9915628.255	681328.766	1494.119	72
GPS4	9915815.053	681594.506	1489.554	72
GPS5	9916056.582	685712.583	1711.340	72
GPS6	9915952.814	686034.305	1725.857	72
GPS7	9913842.248	689145.250	1762.931	72
GPS8	9913717.424	689270.714	1754.792	72
GPS9	9911934.023	691947.938	1585.832	72
GPS10	9912143.294	692118.249	1579.875	72
130T18	9921512.440	690542.440	1782.810	72


RONGO - OGEMBO ROAD
GPS SURVEY
E700000
E690000
E680000
E670000
N9930000
N9920000
N9910000
GPS1
GPS2
GPS3
GPS4
GPS5
GPS6
GPS7
GPS8
GPS9
GPS10

BUMALA - PORT VICTORIA

Point Id	X-Coord	Y-Coord	Z-Coord	Point Code
101T7	38641.870	628223.270	1328.230	72
TP1	33949.910	633785.007	1285.784	72
TP2	33899.209	633724.092	1286.824	72
GPS3	31847.637	629227.098	1293.696	72
GPS4	31875.798	628683.961	1298.075	72
GPS4A	31999.448	628439.893	1298.958	72
GPS5	31036.772	624129.951	1237.579	72
GPS6	31000.128	623864.704	1231.839	72
GPS7	29946.296	620152.700	1191.111	72
GPS8	29797.036	619835.526	1197.787	72
GPS9	27403.095	616400.206	1149.799	72
GPS10	27110.634	616214.049	1149.115	72
GPS11	23492.969	614354.870	1157.431	72
GPS12	23363.961	614388.930	1159.334	72
GPS13	20319.070	614324.663	1217.944	72
GPS14	20073.880	614258.599	1211.804	72
GPS15	15961.593	612772.208	1153.675	72
GPS16	15677.383	612809.658	1142.324	72
GPS16A	15231.502	612620.490	1148.033	72
GPS17	11910.564	610248.111	1165.240	72
GPS18	11680.067	609854.412	1173.542	72
GPS19	11106.661	609000.766	1148.429	72
GPS20	11026.509	608863.924	1147.334	72
101T48	10397.700	607681.330	1329.600	72


BUMALA - PORT VICTORIA ROAD
GPS SURVEY

TRAVERSE POINTS FOR ROAD C19 (HOMA BAY - MBITA)

TP No.	Northing	Easting	Height
1	9939231.375	661539.955	1236.928
2	9939163.540	661394.660	1241.720
3	9939140.764	661208.816	1243.534
4	9939080.869	661088.855	1242.305
5	9938893.094	660861.944	1239.216
6	9938743.463	660771.953	1235.257
7	9938544.672	660566.903	1231.941
8	9938361.240	660495.425	1232.765
9	9938111.791	660311.996	1234.372
10	9938004.033	660235.858	1233.230
11	9937683.494	660111.850	1236.506
12	9937529.670	660031.649	1235.127
13	9937302.156	659940.117	1230.763
14	9937128.004	659817.401	1234.374
15	9936815.584	659732.212	1241.080
16	9936659.077	659662.794	1244.246
17	9936218.861	659459.093	1258.097
18	9936026.581	659393.694	1265.312
20	9935755.806	659219.319	1277.921
21	9935438.852	659093.242	1299.828
22	9935238.926	659081.145	1312.798
23	9935026.216	659070.036	1318.444
24	9934831.871	658860.956	1322.773
25	9934594.375	658408.512	1325.444
26	9934445.843	658175.489	1326.600
27	9934274.230	658071.185	1327.098
28	9933882.328	657776.306	1329.712
29	9933674.569	657583.457	1332.144
30	9933577.066	657381.280	1320.269
31	9933659.581	657310.211	1309.695
32	9933670.283	656826.028	1294.028
33	9933719.020	656597.100	1298.788
34	9933720.086	656410.842	1297.640
35	9933884.339	656190.069	1294.086
36	9934114.153	656066.746	1293.760
37	9934239.272	656099.792	1288.982
38	9934403.469	655993.409	1277.320
39	9934410.730	655884.455	1271.489
40	9934826.308	655333.178	1253.187
41	9935073.082	655035.855	1256.552
42	9935261.820	654770.544	1253.079
43	9935412.599	654347.802	1234.900
44	9935747.788	653936.407	1228.665
45	9935842.294	653750.942	1232.044
46	9935904.709	653563.548	1234.646
47	9936225.066	653080.566	1249.830
48	9936564.888	652906.490	1259.861
49	9936700.364	652774.120	1269.925
50	9936824.320	652621.792	1283.503

TRAVERSE POINTS FOR ROAD C19 (HOMA BAY - MBITA)

TP No.	Northing	Easting	Height
51	9936829.212	652388.816	1287.877
52	9936851.094	652244.104	1286.108
53	9936834.400	652097.546	1279.739
54	9936850.740	651748.834	1277.632
55	9936932.735	651599.130	1282.703
56	9936949.308	651479.755	1286.082
57	9937045.494	651408.459	1295.104
58	9937101.839	651245.701	1293.420
59	9937284.003	651040.468	1301.927
60	9937391.393	650773.510	1304.882
61	9937377.674	650649.742	1301.519
62	9937226.040	650458.787	1290.847
63	9937221.557	650321.206	1284.179
64	9937394.122	650163.474	1283.435
65	9937537.635	650056.866	1283.211
66	9937593.263	649915.934	1272.698
67	9937777.587	649777.274	1264.927
68	9937974.416	649648.449	1260.366
69	9938230.862	649674.645	1267.343
70	9938531.960	649516.546	1263.185
71	9938707.710	649349.540	1256.487
72	9938861.360	649291.497	1254.728
73	9939290.987	649315.719	1247.078
74	9939633.940	649403.137	1243.839
75	9939746.153	649591.651	1249.286
76	9939891.064	649547.400	1244.666
77	9940206.075	649064.743	1239.456
78	9940546.173	648823.585	1226.935
79	9940639.442	648685.170	1224.010
80	9940774.444	648320.651	1220.545
81	9941387.863	647748.646	1211.904
82	9941919.831	647537.916	1205.793
83	9942317.846	647226.176	1198.010
84	9942711.372	646928.026	1192.864
85	9943050.997	646727.947	1190.175
86	9943349.558	646571.054	1193.899
87	9943643.289	646446.188	1193.419
88	9943964.154	646392.096	1188.324
89	9944245.261	646326.353	1183.747
90	9944475.786	646144.106	1174.472
91	9944591.742	646064.895	1173.008
92	9944732.170	645839.829	1171.472
93	9945081.427	645532.730	1167.165
94	9945411.577	645305.211	1162.635
95	9945689.434	645069.973	1161.429
96	9945882.676	644934.818	1155.216
97	9946153.261	644861.823	1145.795
98	9946418.934	644725.795	1142.519
99	9946586.840	644429.910	1136.371
100	9946767.719	644265.144	1136.124

TRAVERSE POINTS FOR ROAD C19 (HOMA BAY - MBITA)

TP No.	Northing	Easting	Height
101	9946901.713	644068.566	1135.985
102	9947106.000	643849.782	1136.008
103	9947253.904	643658.733	1137.101
104	9947444.096	643487.927	1136.825
105	9947727.690	643234.614	1144.421
106	9947823.366	643110.024	1137.912
107	9947933.507	642834.503	1136.127
108	9948153.182	642744.240	1135.895
109	9948350.506	642553.851	1136.848
110	9948548.362	642318.840	1137.067
111	9948725.604	642155.344	1138.029
112	9948883.780	642120.245	1135.934
113	9949097.131	642151.718	1135.866
114	9949243.596	642010.690	1138.952
115	9949321.691	641608.435	1169.514
116	9949356.414	641484.717	1170.357
117	9949254.985	641248.537	1173.301
118	9949470.788	641179.910	1166.243
119	9949558.331	641000.609	1165.719
120	9949551.667	640698.121	1159.372
121	9949789.017	640307.881	1144.364
122	9949959.995	640161.748	1144.114
123	9950093.572	639935.098	1144.565
124	9950158.438	639773.420	1146.363
125	9950346.922	639385.973	1146.703
126	9950589.960	639090.876	1164.553
127	9950670.385	639002.156	1170.407
128	9950822.667	638892.021	1169.252
129	9950903.302	638531.577	1155.924
130	9951130.522	638338.551	1144.617
131	9951144.482	637984.593	1144.965
132	9951276.498	637438.600	1148.773
133	9951161.555	637193.755	1154.507
134	9951357.095	636721.899	1142.677
135	9951427.127	636400.961	1146.071
136	9951508.755	636023.936	1148.612
137	9951617.832	635809.471	1155.008
138	9951743.335	635609.931	1150.714
1380	9951840.130	635350.275	1146.975
139	9951995.361	634984.686	1140.788
140	9952244.296	634663.676	1145.822
141	9952397.417	634509.517	1143.109
143	9952867.179	634433.215	1139.955
145	9953142.975	634475.023	1144.967
146	9953301.964	634438.283	1147.390
147	9953567.388	634401.226	1144.257
148	9953663.767	634342.696	1142.926
149	9953908.436	634193.553	1135.726
150	9954263.477	633903.470	1140.583

TRAVERSE POINT FOR ROAD C20 (RONGO - OGEMBO)

TP	Northing	Easting	Height
1	9916404.444	678251.355	1475.750
2	9916161.355	678244.418	1477.900
3	9916085.386	678479.359	1486.327
4	9916070.589	678619.039	1492.003
5	9916006.151	678780.985	1494.927
6	9915966.000	678971.485	1496.781
7	9915896.031	679165.990	1503.143
8	9915863.658	679402.190	1509.369
9	9915761.738	679542.949	1511.495
10	9915640.094	679811.677	1512.802
11	9915492.371	680056.357	1516.243
1011	9915391.675	680241.791	1518.323
12	9915234.807	680442.891	1521.612
13	9915203.120	680654.765	1521.711
14	9915204.945	680770.568	1520.962
15	9915099.595	681003.780	1522.365
16	9915022.569	681227.305	1524.780
17	9914927.609	681551.427	1533.550
18	9914887.402	681651.633	1537.412
19	9915079.321	681633.807	1529.203
20	9915413.946	681473.116	1506.796
21	9915628.255	681328.766	1494.032
22	9915815.053	681594.506	1489.446
23	9915960.553	681869.077	1526.880
24	9916034.063	682132.393	1541.501
25	9916087.464	682316.349	1544.075
26	9916308.862	682699.566	1556.554
27	9916295.077	683123.084	1571.909
28	9916237.844	683349.425	1585.299
29	9916317.655	683666.079	1599.598
30	9916376.554	683783.833	1615.457
31	9916398.160	683869.993	1625.427
32	9916493.526	684136.096	1640.646
33	9916467.289	684259.669	1645.193
34	9916499.493	684476.447	1655.968
35	9916567.271	684573.569	1661.977
36	9916651.604	684808.301	1675.827
37	9916648.167	685050.139	1691.657
38	9916668.507	685204.247	1698.537
39	9916641.133	685354.846	1709.521
40	9916463.766	685487.947	1710.236
41	9916126.348	685578.847	1709.771
42	9916056.582	685712.583	1711.193
43	9915952.814	686034.305	1725.731
44	9915955.843	686141.796	1721.880
45	9915692.898	686588.436	1709.898
46	9915556.403	686653.620	1716.454
47	9915490.374	686880.011	1731.223
48	9915339.263	687000.410	1748.003

TP	Northing	Easting	Height
49	9915061.074	687056.002	1764.927
50	9914987.133	687132.269	1770.165
51	9914989.832	687322.850	1787.514
52	9915103.397	687619.451	1806.558
53	9915086.991	687724.082	1816.756
54	9915006.906	687802.558	1818.655
55	9914947.615	687925.275	1823.788
56	9914792.699	688022.932	1824.804
57	9914590.117	688160.302	1821.766
58	9914374.787	688227.499	1818.899
59	9914208.891	688331.061	1809.550
60	9914129.270	688518.164	1804.635
61	9914127.367	688668.367	1801.088
62	9914166.263	688827.102	1795.679
63	9914029.893	689022.781	1779.218
64	9913911.640	689076.300	1770.558
65	9913842.248	689145.250	1762.849
66	9913717.424	689270.714	1754.702
67	9913632.478	689527.227	1744.802
68	9913426.272	689829.225	1731.076
69	9913303.251	690151.692	1717.236
70	9913452.048	690455.792	1695.828
71	9913429.301	690549.546	1689.640
72	9913317.161	690609.830	1683.405
73	9913081.344	690944.397	1660.037
74	9912944.647	691054.122	1652.209
75	9912831.226	691051.451	1645.609
76	9912611.624	691122.198	1625.929
77	9912692.135	691310.968	1619.647
78	9912677.119	691531.451	1608.169
79	9912740.026	691586.059	1602.894
80	9912678.382	691704.503	1591.105
81	9912506.618	691733.213	1578.752
82	9912229.446	691473.365	1564.270
83	9912205.458	691599.543	1560.827
84	9912265.850	691694.290	1564.429
85	9912311.095	691880.522	1573.324
86	9912258.532	691962.194	1576.593
87	9912204.860	691954.648	1580.169
88	9912013.225	691928.794	1587.857
89	9911934.023	691947.938	1585.662

TRAVERSE POINTS FOR ROAD D250/251 (BUMALA - PORT VICTORIA)

TP No.	Northing	Easting	Height
1	33949.910	633785.007	1285.784
2	33899.209	633724.092	1286.826
3	33940.524	633673.953	1287.590
4	33906.455	633515.800	1291.340
5	33902.376	633319.823	1295.090
6	33860.995	633160.530	1298.259
7	33852.015	633020.055	1299.981
8	33847.029	632877.730	1301.874
9	33791.065	632605.858	1303.632
10	33719.471	632396.828	1302.157
11	33731.718	632207.553	1299.889
12	33728.397	631976.645	1297.106
13	33675.972	631768.029	1296.101
14	33504.546	631548.477	1296.906
15	33421.842	631477.577	1297.722
16	33295.628	631261.384	1301.262
17	33122.261	631041.575	1304.913
18	32995.779	630844.203	1306.205
19	32889.813	630708.400	1304.380
20	32735.309	630560.492	1303.684
21	32546.313	630477.798	1304.784
22	32264.312	630306.211	1303.134
23	32141.924	630173.421	1302.295
24	32047.560	629988.570	1299.069
25	31993.543	629792.271	1297.837
26	31902.119	629552.486	1295.440
27	31847.928	629325.720	1292.972
28	31847.637	629227.098	1293.681
29	31827.145	629086.206	1294.499
30	31830.305	628813.289	1296.828
31	31875.693	628683.924	1297.367
32	31999.430	628439.351	1298.262
33	32136.768	628283.768	1301.150
34	32226.131	628118.875	1303.978
35	32164.264	627979.447	1304.243
36	32009.844	627818.006	1304.150
37	31850.602	627609.236	1301.617
38	31730.755	627374.466	1297.614
39	31653.038	627219.592	1292.793
40	31595.481	627000.841	1285.945
41	31507.187	626818.390	1279.510
42	31456.007	626662.204	1272.454
43	31417.306	626499.629	1264.592
44	31323.503	626295.535	1252.605
45	31211.554	626188.530	1245.393
46	31098.419	626035.217	1248.607
47	31083.497	625929.381	1250.757
48	31114.286	625749.327	1252.948
49	31192.516	625519.779	1253.660

TRAVERSE POINTS FOR ROAD D250/251 (BUMALA - PORT VICTORIA)

TP No.	Northing	Easting	Height
50	31252.665	625307.544	1258.340
51	31191.597	625031.137	1261.162
52	31170.944	624810.495	1261.621
53	31120.914	624600.028	1258.462
54	31110.706	624461.659	1254.148
55	31036.772	624129.951	1242.407
56	30995.468	623987.753	1239.056
57	31000.189	623864.688	1236.652
58	30993.183	623814.766	1236.398
59	31032.232	623616.537	1227.013
60	31085.509	623133.874	1229.033
61	31030.029	622811.983	1234.905
62	30986.420	622542.415	1231.487
63	30971.314	622217.239	1225.651
64	30983.691	622076.462	1222.477
65	30891.874	621810.797	1214.804
66	30801.134	621582.281	1206.799
67	30704.392	621355.019	1197.405
68	30635.354	621079.234	1185.955
69	30342.019	620925.176	1178.289
70	30171.620	620654.060	1172.304
71	30102.051	620529.823	1180.061
72	30043.293	620327.017	1189.061
73	29946.296	620152.700	1195.887
74	29893.016	620034.170	1201.113
75	29797.092	619835.499	1202.577
76	29698.995	619676.793	1201.805
77	29636.195	619563.878	1201.537
78	29371.937	619253.024	1203.431
79	29212.516	619124.135	1203.884
80	29099.815	619002.277	1203.740
81	28838.512	618775.434	1197.787
82	28823.425	618645.179	1192.894
83	28800.418	618351.298	1182.448
84	28816.251	618148.539	1180.290
85	28789.404	617948.911	1178.972
86	28793.039	617785.602	1176.244
87	28771.613	617618.665	1174.561
88	28619.039	617446.474	1179.328
89	28511.651	617352.284	1181.584
90	28391.975	617173.122	1183.362
91	28328.615	617079.167	1182.711
92	28120.488	616891.811	1174.644
93	27975.105	616796.713	1168.014
94	27868.109	616709.314	1164.207
95	27614.388	616538.198	1156.299
96	27403.095	616400.206	1154.629
97	27110.634	616214.049	1153.949
98	26863.927	616137.939	1159.605

TRAVERSE POINTS FOR ROAD D250/251 (BUMALA - PORT VICTORIA)

TP No.	Northing	Easting	Height
99	26731.227	616050.885	1166.581
100	26628.281	615869.370	1169.397
101	26500.180	615685.993	1170.776
102	26321.968	615420.556	1167.884
103	26208.894	615214.736	1163.157
104	26127.821	615107.981	1160.195
105	25999.975	614894.735	1155.911
106	25769.355	614546.129	1146.392
107	25630.716	614310.606	1145.968
108	25477.137	614091.384	1150.530
109	25385.034	613929.911	1154.795
110	25216.226	613691.773	1159.818
111	25004.137	613610.603	1162.746
112	24915.497	613727.897	1164.729
113	24833.560	613895.917	1163.069
114	24644.946	614003.813	1159.641
115	24503.907	614014.700	1155.623
116	24183.288	614177.325	1150.449
117	23916.121	614229.375	1155.962
118	23589.881	614347.362	1161.699
119	23492.969	614354.870	1162.456
120	23363.961	614388.930	1164.379
121	23246.697	614449.465	1167.011
122	23089.998	614581.904	1171.841
123	23012.285	614701.568	1175.054
124	22950.527	614966.006	1185.506
125	22912.209	615079.985	1190.610
126	22918.928	615339.114	1202.985
127	22957.682	615465.410	1208.398
128	22546.088	615228.305	1213.745
129	22240.920	615029.836	1217.621
130	21903.592	614823.010	1226.587
131	21660.038	614652.234	1225.176
132	21165.420	614526.894	1239.529
133	21002.483	614478.550	1236.785
134	20723.889	614420.516	1230.907
135	20465.073	614348.758	1225.913
136	20319.070	614324.663	1223.230
137	20073.880	614258.599	1217.101
138	19451.766	614129.883	1216.131
139	19123.757	613986.337	1216.070
140	18956.389	613897.589	1213.733
141	18830.749	613843.146	1209.827
142	18661.618	613739.300	1203.896
143	18405.069	613620.664	1191.208
144	18245.281	613523.146	1185.947
145	18099.032	613377.559	1177.901
146	17810.353	613146.109	1164.816
147	17577.283	612930.617	1168.167

TRAVERSE POINTS FOR ROAD D250/251 (BUMALA - PORT VICTORIA)

TP No.	Northing	Easting	Height
148	17447.929	612820.095	1170.157
149	17206.708	612617.944	1174.151
150	16941.973	612451.497	1179.289
151	16799.906	612348.929	1180.943
152	16675.897	612343.955	1185.021
153	16606.874	612384.785	1188.238
154	16568.353	612468.330	1189.680
155	16489.041	612555.323	1189.824
156	16305.141	612624.065	1183.177
157	16257.617	612677.560	1178.816
158	16115.500	612678.507	1171.007
159	16008.151	612715.764	1165.883
160	15961.593	612772.208	1159.188
1601	15801.932	612826.885	1150.668
161	15677.392	612809.700	1147.843
162	15393.130	612686.833	1149.935
163	15216.116	612612.400	1154.373
164	15017.742	612455.960	1156.621
165	14819.851	612165.891	1147.310
166	14593.940	611877.860	1146.417
167	14406.208	611519.075	1145.503
168	14293.372	611407.891	1146.656
169	13983.467	611575.784	1148.837
170	13810.450	611545.941	1156.635
171	13530.641	611452.125	1162.112
172	13313.445	611403.455	1165.149
173	12968.702	611294.474	1172.387
174	12915.007	611205.432	1172.436
175	12740.864	611201.526	1164.446
176	12498.040	610914.903	1166.766
177	12373.448	610820.723	1167.135
178	12258.534	610690.249	1167.616
179	12137.597	610589.201	1167.686
180	11910.564	610248.111	1170.992
181	11680.067	609854.412	1179.312
182	11584.838	609672.004	1178.880
183	11459.730	609435.524	1172.571
184	11417.483	609313.672	1165.231
185	11330.141	609173.313	1158.941
186	11226.216	609033.119	1153.026
187	11106.661	609000.766	1154.198
188	11026.509	608863.924	1153.109
189	11031.328	608832.344	1153.198
190	11027.746	608587.987	1157.301
191	11036.478	608569.518	1157.898
192	11102.543	608495.844	1157.644
193	11139.739	608243.588	1159.557
194	11142.952	607980.799	1155.920
195	11070.479	607799.688	1155.089

Appendix 7.2 Material Testing Analysis And Countermeasures for Design Purpose

Material Testing Analyses And Counter Measures For Design Purposes

1. Introduction

1.1 Fundamental Objective

The fundamental objective of this Study is to foster the importance of carrying out comprehensive analyses of Material Test Results as opposed to the conventional style of merely reporting the quantitative results. This is to facilitate the determination of appropriate and suitable countermeasures for a more economic design.

1.2 Importance Of Material Testing And Rationale For Enhanced R&D In Kenya

Geotechnical Engineering problems have in most cases been of a complex and diverse dimension necessitating a cautious approach in the determination of design parameters and construction methods. Solutions to Geotechnical Engineering problems can therefore only be obtained through the determination of basic properties of the geomaterial and employment of analytical methods taking into account intelligent application of the laboratory Test Results to actual Geotechnical Engineering problems.

In Kenya, the current Road Design approach is predominantly based on methods that have been developed for testing geomaterials within temperate and not tropical regions notwithstanding the fact that most of the geomaterials that exist in the two zones have significantly different characteristics. As a consequence, uneconomical or structurally deficient designs are inevitably adopted.

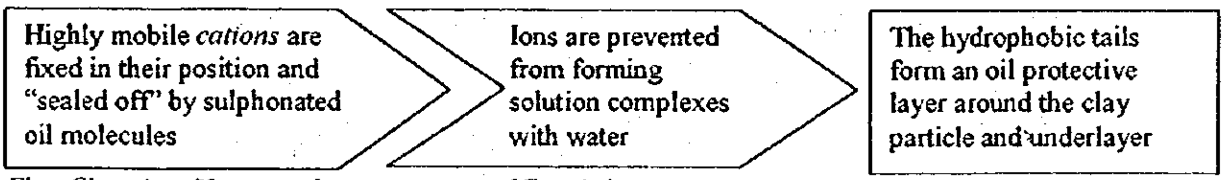
Furthermore the existing data has hardly been correlated, properly analyzed or even developed into a useful databank and very little scientific data based on research oriented laboratory and field testing has been published or availed publicly. Consequently enhancement of Research and Development activities is considered inevitable for industrialization.

2. Basic Properties Of Materials Tested

2.1 Properties and Action of Stabilisers

- *Con-Aid*

Con-Aid is a liquid chemical stabiliser whose essential feature is to curb the clay water interaction through expulsion and repulsion of the aBsorbed and aDsorbed water. Through ionic exchange chemical reaction, the sulphonated oil in Con-Aid whose chemical consistency consists of a hydrophilic head (a sulphonic acid moiety) with the ability to dispel absorbed water and "permanently" prevent its re-adsorption. This is characterised by the fact that the molecules dissociate when the oils disperse in water and produce an anionic SO_3 group that is linked by the sulphur atom to the tail of the molecule which ensures the achievement of the affinity between Con-Aid and the clay particle. The hydrophilic head of the sulphonated oil forms chemical bonds with the surfaces of clay particles on both external and on the planar surfaces whose interaction with the clay minerals result into the following flow: -



Flow Chart 1: Theoretical representation of Con-Aid reaction

For further details refer to Con-Aid Research and Development proposal by Mukabi (1998).

- *Lime*

Lime is Calcium Oxide (CaO) that is manufactured by heating crushed carbonate rock (Limestone or dolomite) to very high temperatures. Limestone is made of calcium, carbon and oxygen, whereas dolomite contains magnesium in addition to these chemicals. Addition of lime to a soil generally results in decreased soil density, changes the plasticity properties of soil and increases soil strength which are as a result of several reactions that alter the water surrounding the clay minerals and/or form new materials from the soil components through pozzolanic action. Increase in strength of lime treated geomaterial is dependent upon the charge, size and hydration of attracted ions.

2.2 *Materials Tested*

The materials tested in this study are mainly from Alignment Soils and Material Sites. Details regarding sampling locations, topography, general geology etc. of these areas are addressed in the Materials Report of the Study on Rural Roads Improvement in Western Kenya of September 1999.The basic properties are shown in Table 2.2.1 and Table 2.2.2.

Table 2.2.1 Basic properties of Natural Alignment Soils (for subgrade)

PROPERTIES:	ROAD:	HomaBay~Mbita	Rongo~Ogembo	Bumala~Port Victoria
	TREATMENT:	Neat	Neat	Neat
ATTERBERG LIMITS	LL (%)	42~71	51~64	39~54
	PI (%)	18~41	23~34	19~26
	LS (%)	11~19	11~17	11~13
COMPACTION	OMC (%)	12.1~18.2	23.5~24.3	11.3~25.0
	MDD (kg/m³)	1580~1785	1584~1475	1510~1995
SIEVING	Passing 0.075mm BS Test Sieve (%)	18~78	47~70	38~70
STRENGTH	CBR(Top/Bottom) (%)	$^{1}/_{3}$~$^{17}/_{24}$	$^{7}/_{6}$~$^{25}/_{6}$	$^{4}/_{6}$~$^{10}/_{10}$
	SWELL under Surcharge≅2.9kN/m²	1.10~5.63	0.24~0.27	0.25~1.00
	UCS (kN/m²) Static/ Dynamic (kPa)			184/940
	Modulus Of Elasticity, E_c [kN/m²] (Static/ Dynamic)			19320/98700

N.B. Only the test results on the lower depth samples at the chainages along the alignments were considered.

Table 2.2.2 Basic properties of natural soils from Material Sites

PROPERTIES	ROAD:	Homabay~Mbita	Rongo~Ogembo		Bumala~PortVictoria	
	M. S. No:	MS 1	MS 2	MS 3	MS 4	MS 5
	TREATMENT:	Neat	Neat	Neat	Neat	Neat
ATTERBERG LIMITS	LL (%)	48~59	41~60	30~51	35 – 64	48 – 65
	PI (%)	22 – 36	16 – 28	13~25	11 – 37	23 – 42
	LS (%)	11 – 18	7 – 13	5~ 12	5 – 14	14 – 20
COMPACTION	OMC (%)	15.6 – 17.5	15.8~18.8	11.0~11.2	10.8 –13.4	9.5 – 18.4
	MDD (kg/cm³)	1775~1850	1705~1780	1965~1975	1915	23 – 29
SIEVING	Passing 0.075mm BS Test Sieve (%)	20~ 34	6 ~ 13	17 ~ 26	24 – 65	23 – 29
STRENGTH	ACV(%)	24	25	27	52	37
	LAA (%)	29.3	30.0	41.9	87.0	36.0
	CBRmean (%)	9 – 12	50 ~ 81	38 ~ 44	22 – 48	8~ 30
	SWELL Surcharge ≅2.9kN/m²	2.3~ 2.7	0.22 –0.3	0.73 – 1.2	0.3 – 0.8	0.6 – 2.0
	1 Day Mould Cured UCS [kN/m²]				123	193
	Modulus Of Elasticity (E_c) [kN/m²]				12915	20265

3. Testing Method

3.1 Conventional Tests

In this Study, the conventional tests were undertaken in accordance with BS1924:1990 and BS 1377:1990

3.2 Modified Tests

For purposes of simulating certain complex conditions such as dynamic vibrational loading, modification of a number of standard tests had to be done. Details of the modified tests are described in section 2.4 of the Geotechnical Engineering, Materials Testing Analyses Report of October 1999 based on this Study.

4. Definition Of New Equations Proposed And Applied In Study

When characterizing the behavior of a geomaterial it is of great importance to analyze its various physio~chemical and mechanical parameters as a counter check measure, before settling for a particular design parameter. In view of this therefore, this study undertook to evaluate various characteristics of the geomaterials tested by also adopting already established generalized equations, applying them for comparison purposes and then formulating what may be regarded as relevant relations for the geomaterials tested.

4.1 Calculation of Compression (C_C) and Swelling (C_S) Indices

Assuming a static load such as the surcharge weight from a reasonably high embankment on a subgrade, it would be necessary to evaluate whether or not compression consolidation or settlement would occur and the extent. In such a case a counter measure based on the analyses of the compression index (C_C) would be imperative.

An appreciably accurate relation between the swell index C_s and the swell properties of particularly expansive soils such as Black cotton soil is also considered to be vital. This precedence has therefore led to the analysis of the C_C and C_S indices. Various research on Japanese Clay has shown that for a Normally consolidated Alluvial Clay the following relation can be applied fairly satisfactorily.

$C_C = 0.009\,(W_L - 10)$ ....(4.1.1)

Where W_L is the Liquid Limit

Wroth (1979) proposed the following correlation relating the compressibility Index (C_C) and the plasticity Index (PI) for $G_S = 2.64$

$C_C = \{0.5\, G_S \bullet PI / 100\}$ ....(4.1.2)

Matsuda et al. (1994) reported that for undisturbed clay, the correlation between C_C and PI is better presented as follows: ~

$C_C = \{0.7\, G_S \bullet PI/100\}$ ....(4.1.3)

Yasuhara et al. adopted the following simple empirical relation proposed by Ue et al.

$C_S/C_C = 0.185 + 0.002\,PI$ ....(4.1.4)

In this study, C_c was first calculated using equations 4.1.1 ~ 4.1.3 and C_S was calculated from the correlation expressed in equation 4.1.4.

The concept of compression and swelling was also extended to the pre~ and post~swelling quantitative values of dynamically loaded specimens as shown in the schematic Fig. 4.1.1 and the subsequent calculations leading to equations 4.1.5~4.1.8. Figure 4.1.1 shows concept relating C_C, C_S, $(q_u)_D$ and E_D in compression and swelling zones.

Hence as shown in this schematic, linear regression analyses were made and the following expressions derived from Figs. 4.1.2 ~ 4.1.5.

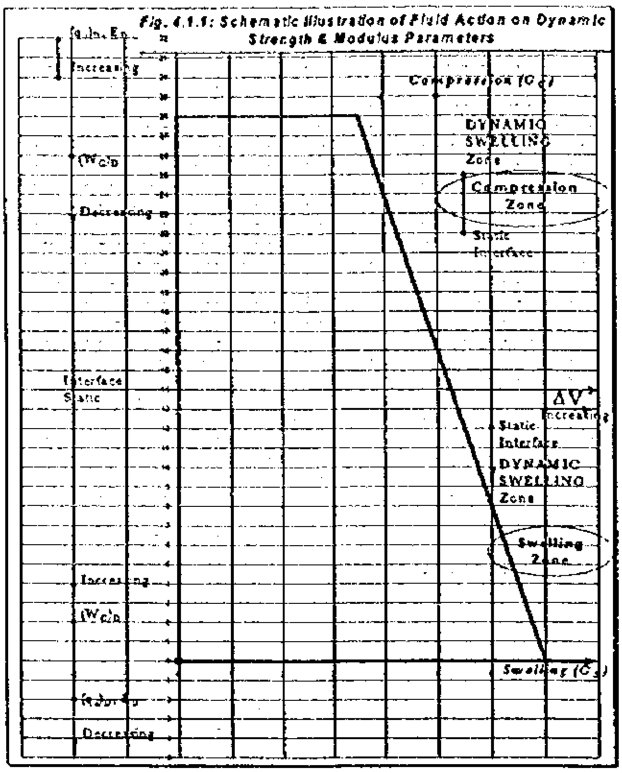
$(q_u)_{AMC}/(q_u)_{max,D} = \sim 0.0123PI + 0.535$ ....(4.1.5)

$\{(E_{50})_{T,D}\}_{AMC}/(E_{50})_{T,D} = \sim 0.0185PI + 0.823$ .....(4.1.6)

$\{(E_{max})_D\}_{AMC}/(E_{max})_D = \sim 0.0362PI + 1.9$ ....(4.1.7)

$\{(E_{max})_D\}_{AMC}/(E_{max})_D\} = \sim 23.5\, C_S/C_C + 6.44$ ....(4.1.8)

Where $\{(q_u)_{max,D}\}$, $(E_{max})_D$ are the maximum strength and elastic modulus respectively and AMC stands for Adjusted Moisture Content.



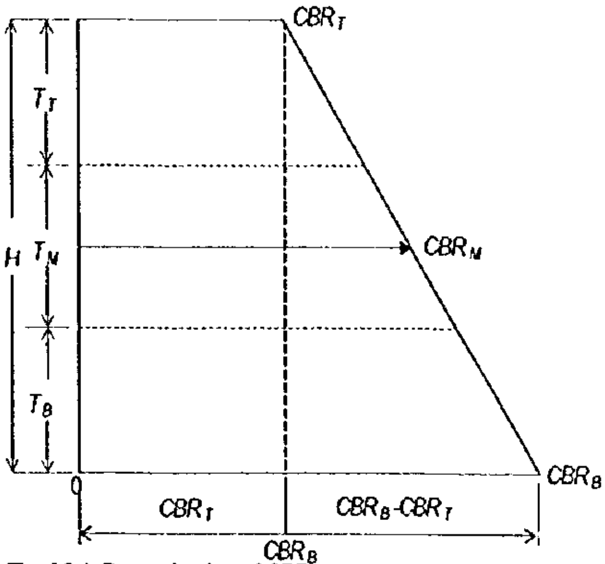
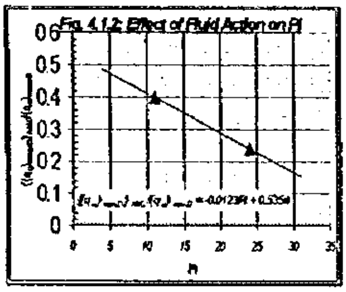
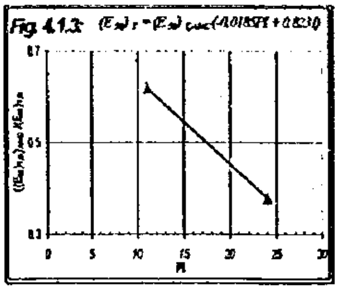
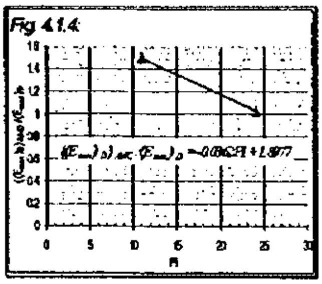
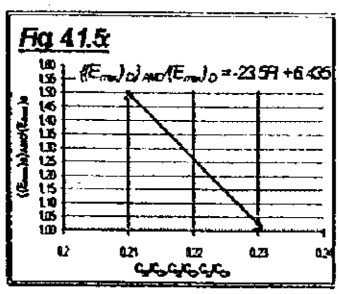


Fig. 4.2.1: Determination of CBR_{mean}









4.2 *Calculation of Mean CBR*

Where the Top and Bottom CBRs varied by more than 10%, the following formula which is modified and proposed in this Study was adapted :~

$$CBR_M = \left\{ \frac{T_T CBR_T^{1/3} + T_M CBR_M^{1/3} + T_B CBR_B^{1/3}}{H} \right\}^3 \quad \text{.........................(4.2.2)}$$

and

$$CBR_M = \{CBR_B - CBR_T\} \times 0.5 + CBR_T \quad \text{.....................................(4.2.3)}$$

as shown in the schematic figure above (Fig. 4.2.1).

4.3 *Derivation of Moduli Parameters*

The dynamic behaviour of a subsoil under seismic loading due to earthquakes or vibrational loading as a result of traffic, vibrating machines blast, shock or impetus loading and characterization of the corresponding deformation is a subject of great importance.

However, determination of such parameters is usually expensive and practically unaffordable for developing countries. Since these parameters are vital for relatively precise designs of structures, this study set out to develop various empirical relations that may assist in the estimation of such parameters as E_{max} (Maximum Elastic Modulus) which require complex and costly methods of testing.

- *Maximum Young's Modulus*

Based on experimental test results on natural and artificial clays by Mukabi (1991,1995) the following relation derived from Fig. 4.3.1 was determined.

$E_{max} = \{(E_{50})_{1}/(0.0996q_{max} - 0.1042)\} \times 98.1\ (kN/m^2)$..(4.3.1)

$E_{max} = \{(E_{50})_{1}/(0.0249q_{max} - 0.1042)\} \times 98.1\ (kN/m^2)$..(4.3.2)

This equation was adopted in the calculation of E_{max} values from Unconfined Compression test results reported in Section 5 of this paper.

Fig. 4.3.1: E_{max} Vs. q_{max} for Kaolin

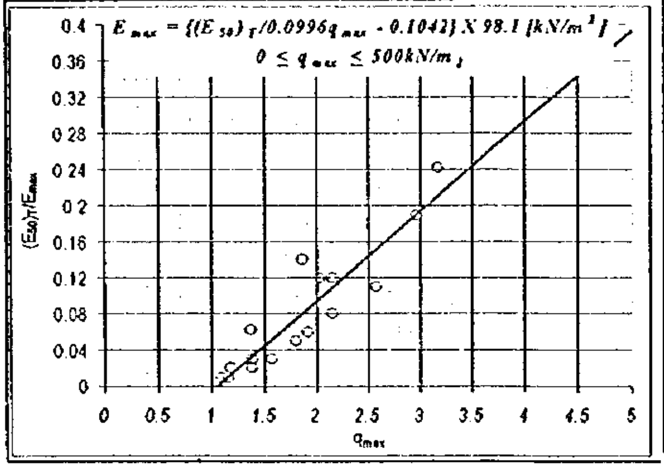
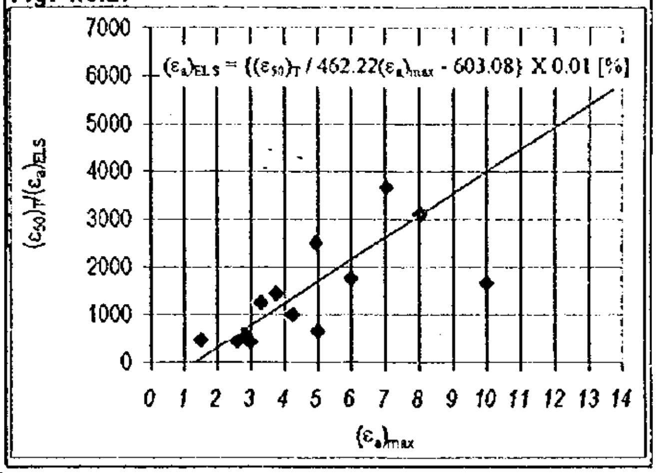


Fig. 4.3.2:



- *Elastic Limit Strain*

In order to determine the corresponding strain within the linear elastic region, the concept of Elastic Limit Strain (ELS) first proposed by Mukabi (1991) was applied. In developing this concept, Mukabi (1995) considered a decay ϕ factor which defines the strain level dependency of stiffness to resolve that:~

$(\varepsilon_a)_{ELS} = (\varepsilon_a)_{RS} \times \phi_{factor}$.. (4.3.3)

Where, $\phi factor = (Et)_{RS}/E_{max}$,

$(\varepsilon_a)_{RS} = \{\Delta q_\phi \sim 0.01 \times (\varepsilon_a)_\phi \times E_t\}/\{0.01\ E_{max} - E_t\}$

and E_t: Arbitrarily determined tangent modulus, RS: Reference Strain.

Based on these equations therefore, this study related the ratio between $(\varepsilon_a)_{50}/(\varepsilon_a)_{ELS}$ to (ε_a)max determined from corresponding triaxial compression tests to develop the relation shown in Fig. 4.3.2 expressed as:~

$(\varepsilon_a)_{ELS} = [(\varepsilon_{50})_T/\{462(\varepsilon_a)_{max} - 603\}] \times 0.01(\%)$.......................... (4.3.4)

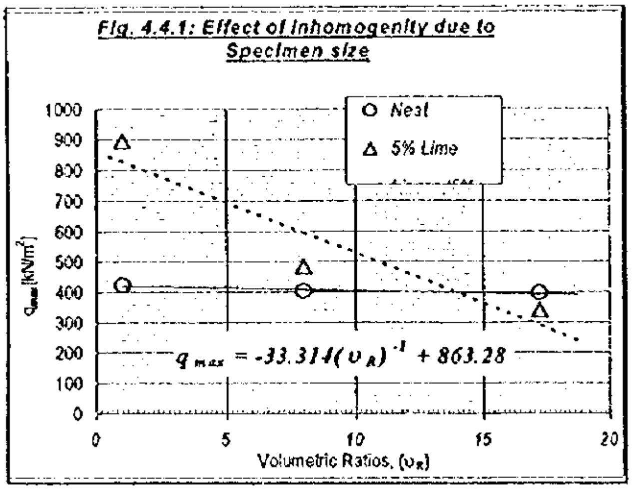
- *Modified Resilient Modulus*

The Resilient Modulus (M_R) is defined as a dynamic test response expressed as a ratio of repeated axial stress σ_D to the recoverable axial strain $(\varepsilon_a)_{ELS}$. In this study, the modified Resilient Modulus was calculated from the following equation whose the recoverable strain was the calculated $(\varepsilon_a)_{ELS}$ based on the relation in (4.3.4)

$(M_R)mod = \sigma_D/(\varepsilon_a)_{EL S}$ .... (4.3.5)

4.4 Determination of Correction Factor for Maximum UCS due to inhomogenity

From various tests using different sizes and shapes of moulds the following relation derived from Fig. 4.4.1 by linear regression, was used in determining a correction factor for the maximum UCS.



$q_{max} = -33.3\ v_R^{-1} + 863.3$ .... (4.3.6)

Where VR^{-1} is the inverse volumetric ratio.

5. Analyses Of Test Results

In order to characterise the geomaterials tested for purposes of determining precise design parameters and recommend appropriate countermeasures and construction techniques, numerous tests were performed. The fundamental characteristics studied were plasticity, compaction, strength and deformation, modulus of deformation as well as swell behaviour in relation to various effects such as mechanical stabilisation, curing period, curing mode, loading mode, surcharge pressure and fluid action among others.

5.1 Plasticity Characteristics

Variations in plasticity characteristics have been known to largely influence the swell behaviour and deformation of geomaterials. A group of Tropical Soils have been known to show changes in these characteristics upon drying mainly due to the alteration of clay minerals on dehydration and aggregation of fine particles to form larger particles in the presence of cementing agents. Furthermore, plasticity is considered to indirectly influence the microstructure, compressibility and strength. Plasticity properties were determined from samples subjected to various curing levels, moulding conditions and modes of treatment.

- *Effect of Treatments*

  The results plotted in Figs. 5.1.1(a)~(c) show that the plasticity from bulk cured samples decreases tremendously with increase in lime content for virtually all five material sites (MS). Con~Aid + 2% lime is more effective in reduction of plasticity than plain 2% lime. In terms of plasticity, material from MS1 responds best to increase in lime content. Similar trends can be observed from the UCS mould and compaction cured samples. In general, the PI values from bulk material appear to be less than those subjected to Compaction. Some influence of treatment can also be observed.

Fig. 5.1.1(a): Effect of Treatment on PI from Bulk cured sample

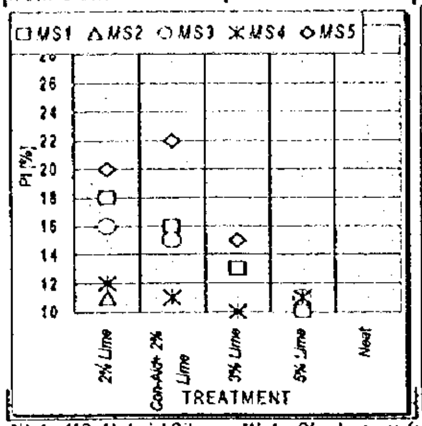


Fig. 5.1.1(b): Effect of Treatment on PI from crushed UCS Mould cured

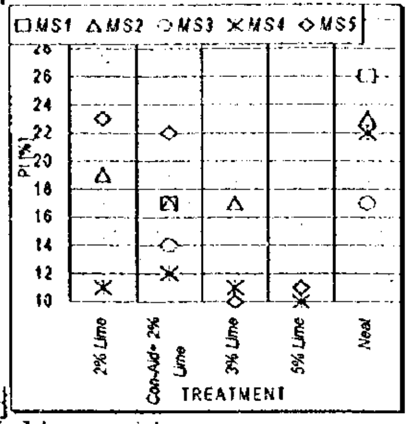
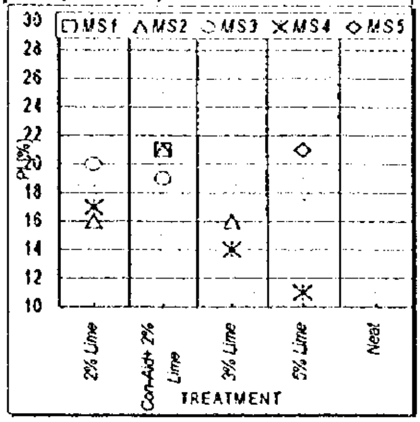


Fig. 5.1.1(c): Effect of Treatment on PI from post compaction Bulk cured



*Note- MS: Material Site *Note- PI values are for 7 day cure period

- *Curing Period and Sample Source Effect*

No significant influence of curing period on PI can be observed from Figs. 5.1.2 (a) ~ (d). It may seem that when a material is treated, the PI drops almost immediately (within 1 day cure) after which the Characteristics hardly vary with curing period. This may imply that curing does not play a significant role in reducing the PIs. The relatively higher values from Post~Compaction samples implies that compaction breaks the soil particles, hence increasing the portion finer than 2mm which leads to increased PI. This factor should therefore be taken into account during design. It is also deemed important to carry out further research that would guide towards a generalised state of estimating a compaction related "Crush factor" considering the effects of curing.

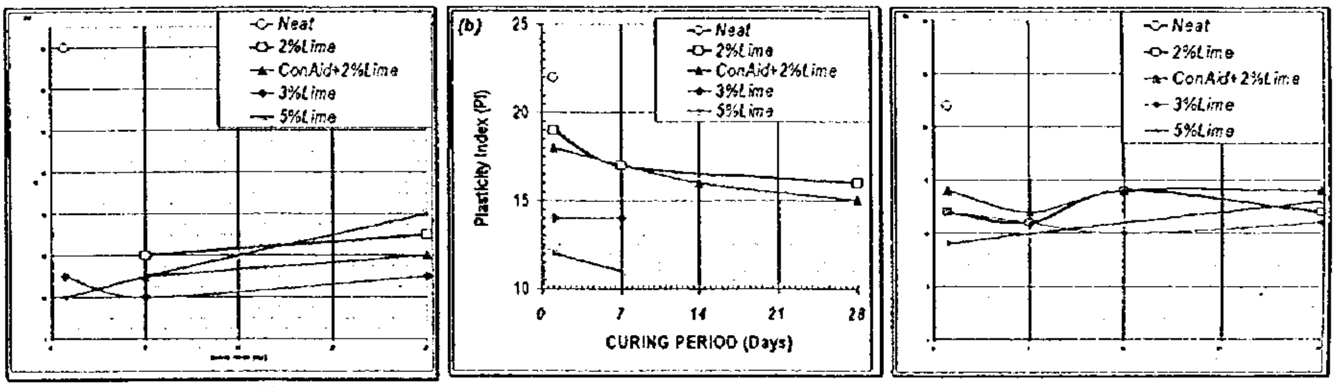


Fig. 5.1.2(a)~(c): Effect of curing period on PI

5.2 Compaction Characteristics

Mechanical compaction is known to strengthen the soil particle contacts through meniscus effects with low water contents. However, this effect becomes hampered by increased quantities of water beyond the OMC (Optimum Moisture Content) due to retardation in capillary attraction as a result of increased water layer around the soils particles. It is therefore necessary to study Compaction Characteristics under the influence of different treatments and curing periods and whether these factors vary with the type of geomaterial being tested.

- *Effect of Treatment*

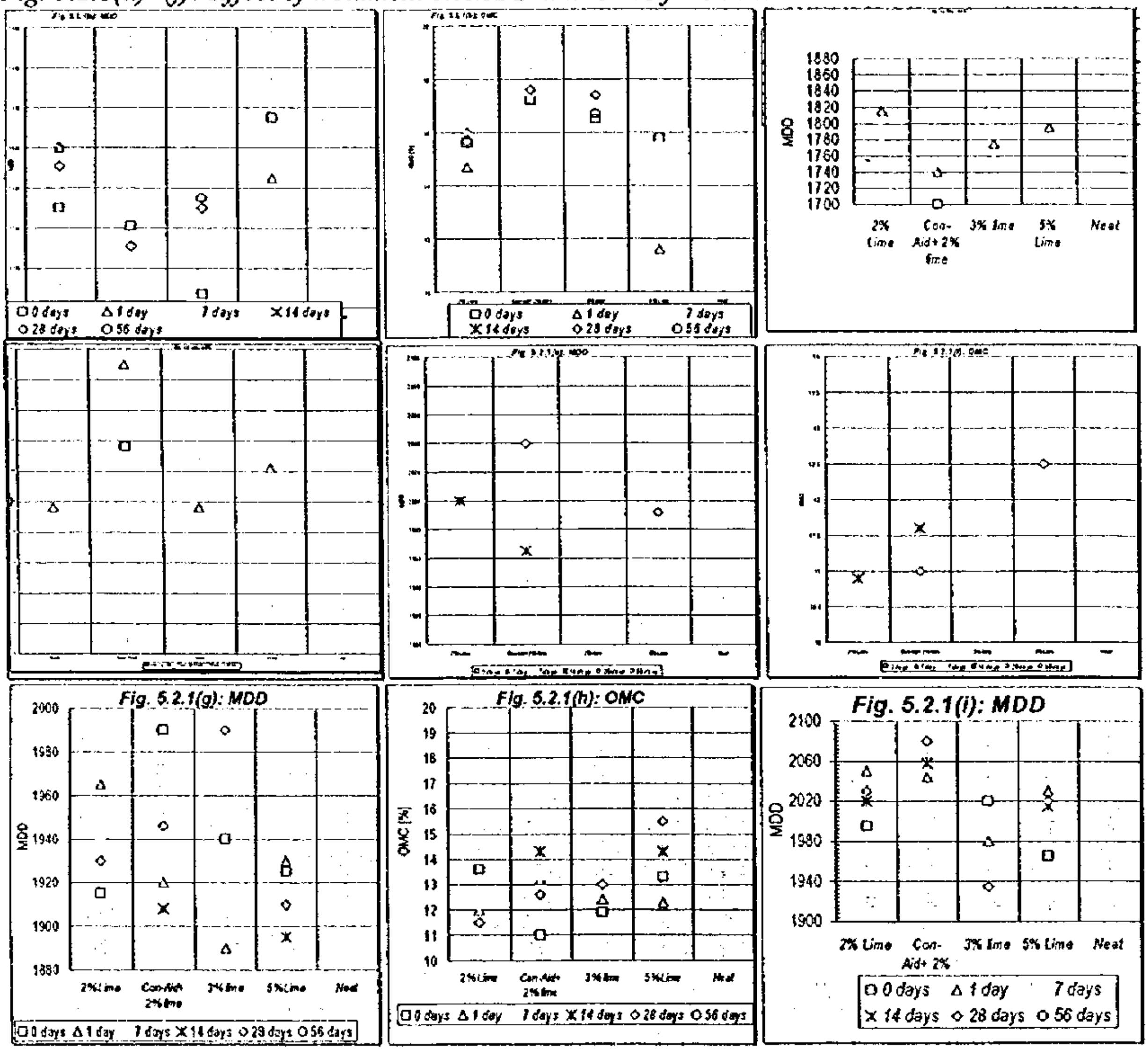
The effect of treatment was studied by using the five different types of materials sampled from the material sites and treated by 2% lime, Con~Aid + 2% lime, 3% lime and 5% lime. It can be seen from the results on MDD and OMC presented in Figs. 5.2.1(a) ~ (j) that:-

(i) No unique relationship can be derived between the mode of treatment and Maximum Dry Density (MDD) or Optimum Moisture Content (OMC). However, for MS1, the tendency of increasing the lime content is to reduce the magnitude of the MDD but not necessarily in consistence with the effect on OMC.

(ii) The overall observation made from these results is that there exists an optimum mode of treatment which is influenced by the lime content whose value is close to the ICL. Excessive treatment does not necessarily yield higher MDD and lower OMC values but seems to highly depend on the fines content of the material.

(iii) On the average it seems that Con~Aid + 2% lime treatment yields the highest MDD values for the various materials. From the above derivations it may seem that Con~Aid and lime complement each other in achieving appreciable MDDs which are consistent with the reduction in OMCs for most materials tested.

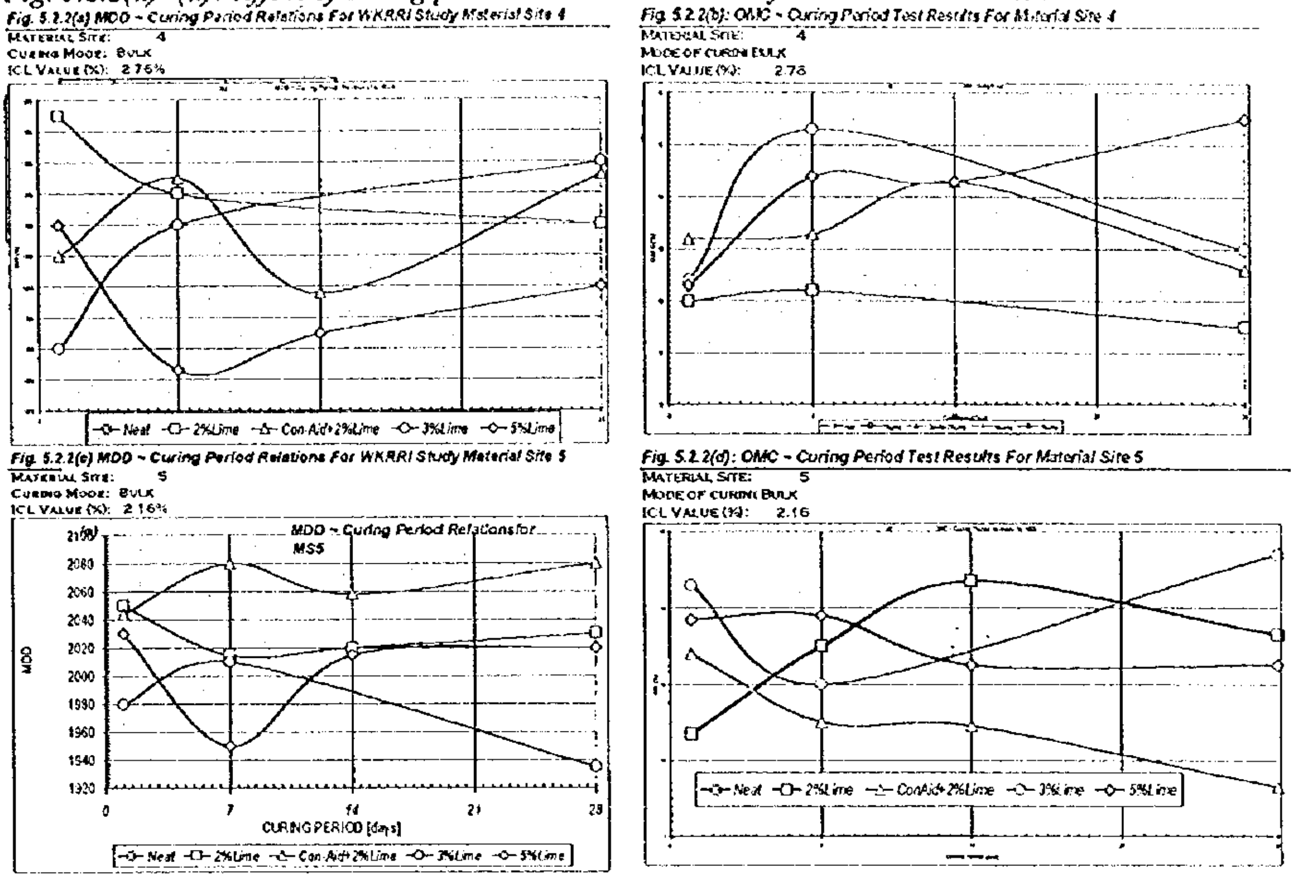
Fig. 5.2.1(a)~(j): Effect of treatment on MDD and OMC for Material Sites 1~5



- *Effect of Curing Period*

Figs. 5.2.2 (a) and (c) depict the relations between MDD and Curing Period while Figs. 5.2.2 (b) and (d) show the corresponding OMC ~ curing period relations for MS4 and MS5 respectively. It is quite interesting to note from these figures that:~

Fig. 5.2.2(a)~(d): Effect of curing period on MDD and OMC for Material Site 4 & 5



(i) Whereas the other treatments exhibit erratic behaviour, the 3% lime treated material shows a consistent increase in MDD with curing period yielding the highest MDD = 1950 kg/m^3 after 28 days of cure for material sampled from MS4 (ICL = 2.76%). Again, it can be seen that for MDD the major controlling factor is the ICL value.

(ii) For both MS4 and MS5 the lime treated materials drastic changes occur after 7 days cure and by either increasing or reducing in MDD almost consistently with curing period. The Con-Aid + 2% lime treated material seems to stabilise after 14 days cure whereby it increases in MDD with increasing curing period to yield almost the highest values.

(iii) For MS4 the OMC Characteristics are similar in trend to the MDD ones.

For MS5, the trends are not consistent for the lime treatments but a consistent reduction in OMC with lime for the Con-Aid + 2% lime treatment particularly after 14 days cure can be well observed. The Con-Aid time dependent and water expulsion features can be well observed from the above results (Also refer to Con-Aid Report). The above results suggest that lime treatment of contents close to the ICL values is most effective on the compaction characteristics whilst Con-Aid + 2%lime treatment yields the best results for almost all the materials.

- **Compaction effect on Dry Density (γ_d) and CBR**

The effect of compaction effort on the dry density and CBR is depicted in Fig. 5.2.3(a) and (b) while the relation between voids ratio (e) and γ_d, CBR_{mean} is shown in Figs. 5.2.3(c) and (d) respectively. The CBR_{mean} was calculated using equation 4.2.1 proposed in this study.

Fig. 5.2.3(a)&(b): Effect of No. of blows on Dry Density (γ_d) and on CBR_{mean}

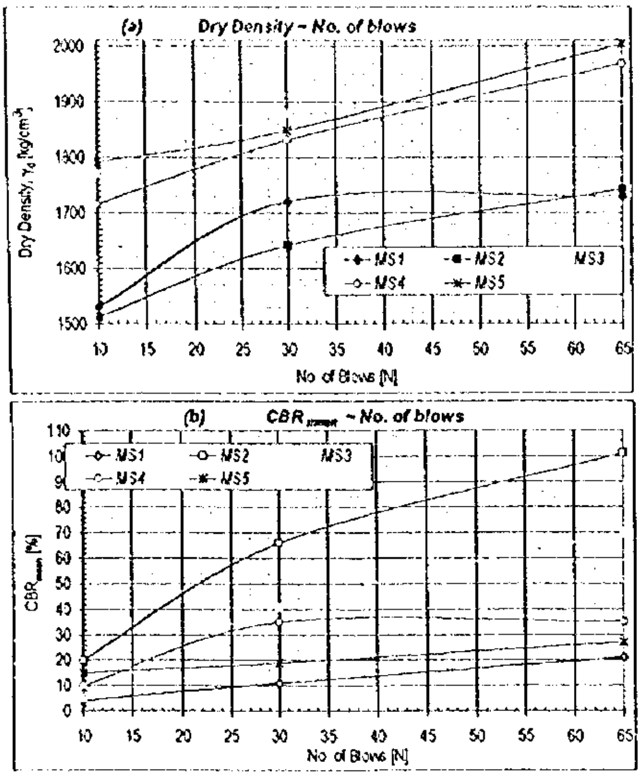


Fig. 5.2.3(c)&(d): Effect of Voids ratio (e) on Dry Density (γ_d) and on CBR_{mean}

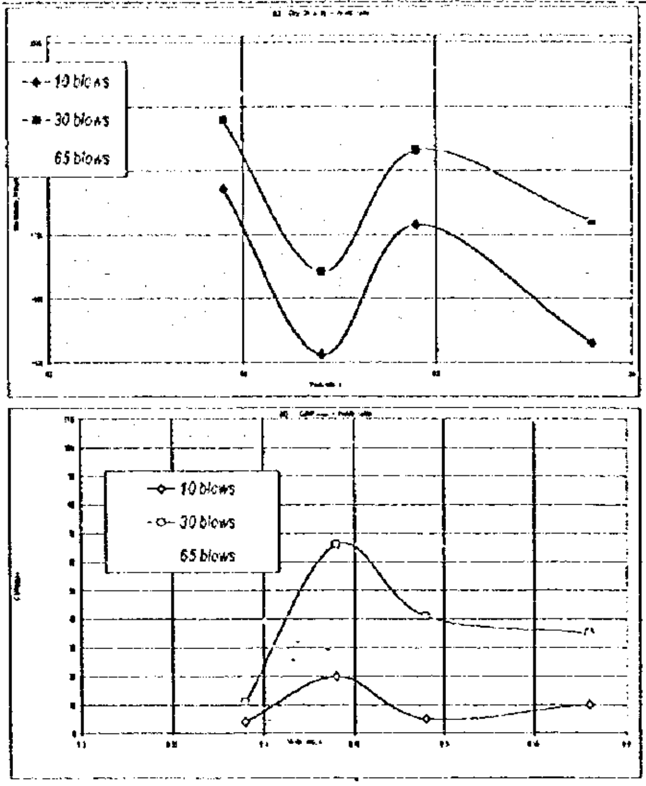


Fig. 5.2.3: Effect of No. of Compaction Blows on CBR and Dry Density

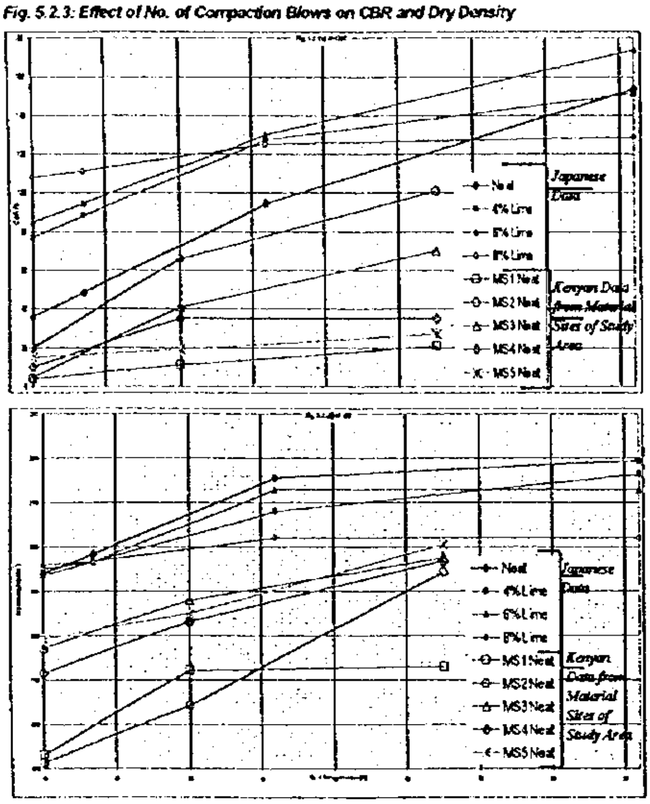
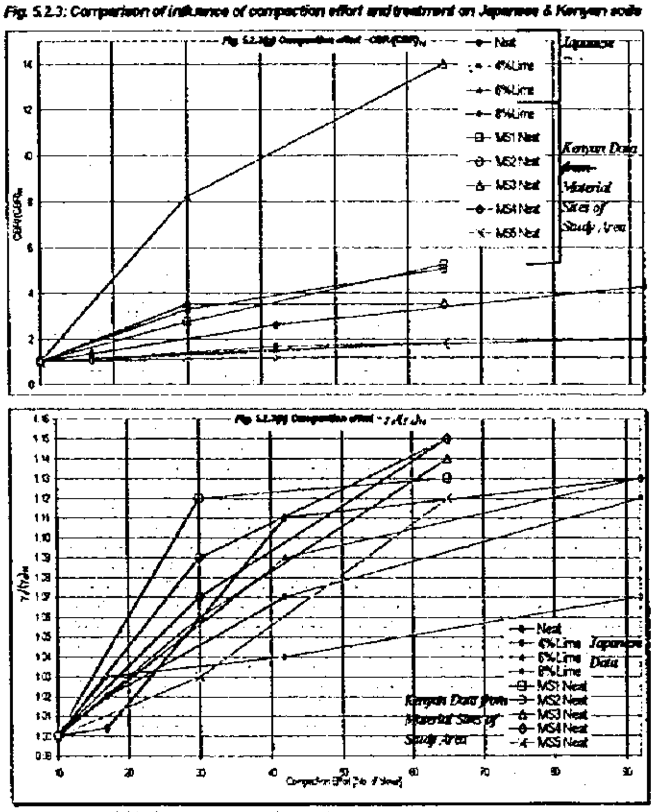


Fig. 5.2.3: Comparison of influence of compaction effort and treatment on Japanese & Kenyan soils



From these results, the following characteristics can be noted :-

(i) The effect of compaction effort on γ_d and CBR_{mean} and the corresponding rate of increase varies with material type.

(ii) The response of γ_d to compaction does not necessarily correspond to that of CBR_{mean}.

(iii) Lower initial dry density results in higher sensitive to compaction effort.

(iv) The variation of γ_d and CBR with voids ratio shows similar trends.

(v) There seems to exist a limiting voids ratio for increase in dry density and CBR Vs reduction in voids ratio or vis versa, which is insensitive to compaction effort.

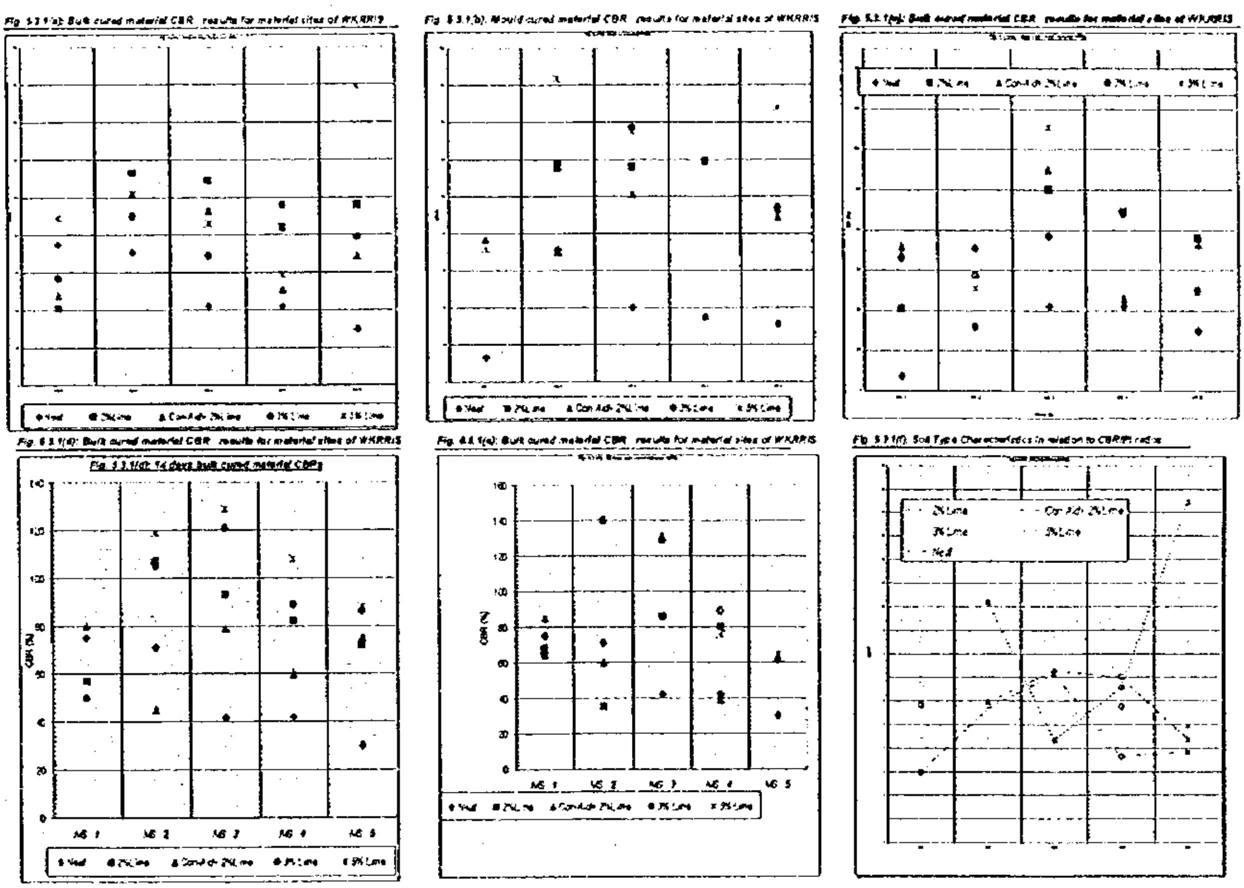
Figs 5.2.3 (e) and (f) compare the effect of compaction on CBR and γ_d for Japanese and Kenyan soils tested while Figs . 5.2.3(g) and (h) depict the same but normalised by the corresponding values at N = 10 blows. It can be seen that for both Japanese and Kenyan geomaterials, CBR and γ_d have propensity to increase at different rates with compaction effort.

5.3 *Strength and Deformation Characteristics.*

5.3.1 *California Bearing Ratio (CBR)*

- *Effect of Treatment*

The characteristics of the various materials subjected for different modes of treatment are summarised in Figs.5.3.1(a)~(e). The general trends indicates that:-
Different materials yield different CBR values notwithstanding the mode of curing or treatment and that the effect of treatment on CBR strength development is fairly significant. Fig. 5.3.1 (f) shows that the effects of PI on the response of CBR strength development to treatment are negligible but that this trend is influenced by curing period.



- *Effect of surcharge pressure*

Prior to construction of a structure on soft ground, advantage can be taken of the surcharge to consolidate the ground in order to increase the strength of the foundation or bearing subsoil.

In this section, the effect of surcharge pressure on CBR and swell is analysed from results presented in Figs. 5.3.2 (a), (b) and (c). These figures indicate that, for the black cotton alignment soils, sampled from km 10+000 and km 35+000 along the HomaBay~Mbita (C19) road treated with Con~Aid, cured for 1 day and tested, an increase of 60% surcharge pressure effects an increase of between 25~50% of CBR strength and a corresponding reduction in swell pressures of around 7~44%.

Fig. 5.3.2: Effect of Surcharge pressure on (a) CBR [%] and (b) SWELL [%]

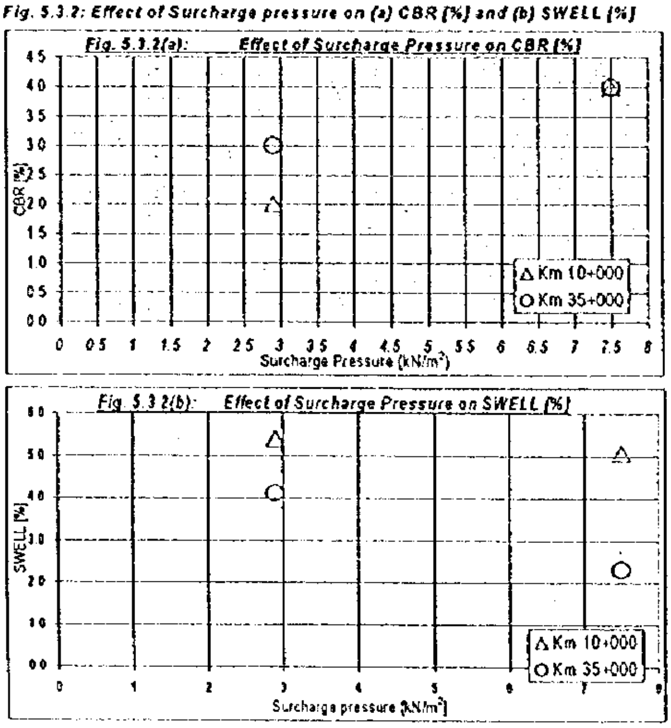


Fig. 5.3.2(c): Effect of Surcharge Pressure on Normalised CBR

Road:	Depth: (m)	Treatment	Chainage:	Surcharge Pressure (kN/m2) 2.9	3.9	5.3	6.4	7.6
				(CBR)/(CBR)ss values				
Homa Bay – Mbita (C19)	0.18–0.7	CON-AID	Km 10+000	1				2
	0.4–0.8	CON-AID	Km 35+000	1				1.33
	0.0–0.8	CON-AID+2% lime	Km 30+000	1	1.13	1.27	1.64	
	0.0–0.9	2% Lime	Km 30+000	1	1.21	1.88		

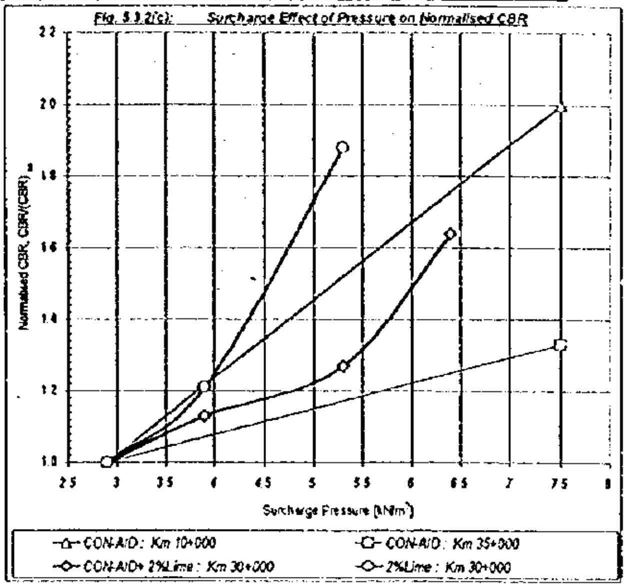


Fig. 5.3.2(c) compares the surcharge pressure effect on normalised CBR (CBR/(CBR)$_{SS}$, where ss stands for standard surcharge = 2.9 kN/m^2) for treated materials. Normalisation was applied to cater for the effects of material type. It can be seen that whereas surcharge pressure increases the CBR virtually linearly for the Con-Aid treated material, the Con-Aid +2% lime treated material depicts quasi~exponential characteristics and exponential for the 2% lime treated material.

- *Effect of curing Mode*

When considering treatment of geomaterials, it is considered necessary to investigate the mode of curing that would result into the fastest rate of strength development and improvement of other parameters related to design and construction. In order to simulate these conditions, various parameters relevant to pavement design were examined from materials cured under bulk and moulded conditions.

Figs 5.3.3 (a) ~ (d) and Figs 5.3.4 (a) ~ (d) show CBR and normalised CBR values for material sites 2 and 3, treated with different modes and cured for 7 days (also refer to Fig. 5.3.1 (b) and (c). These figures show that whereas bulk curing seems favourable for the Con-Aid +2% lime treatment, the lime treatments for materials from MS4 show the CBR from moulded cure to be much higher than that from bulk cured material. For MS5 material however, this difference is not as drastic for both materials; however, the contribution of MDD, OMC and initial PI seems to be minimal. This implies that it is necessary to determine the mode of cure for varying treatments and material type.

Fig. 5.3.3: Effect of Curing mode on CBR, CBR MOD, CBR/OMC & CBR/(PI);

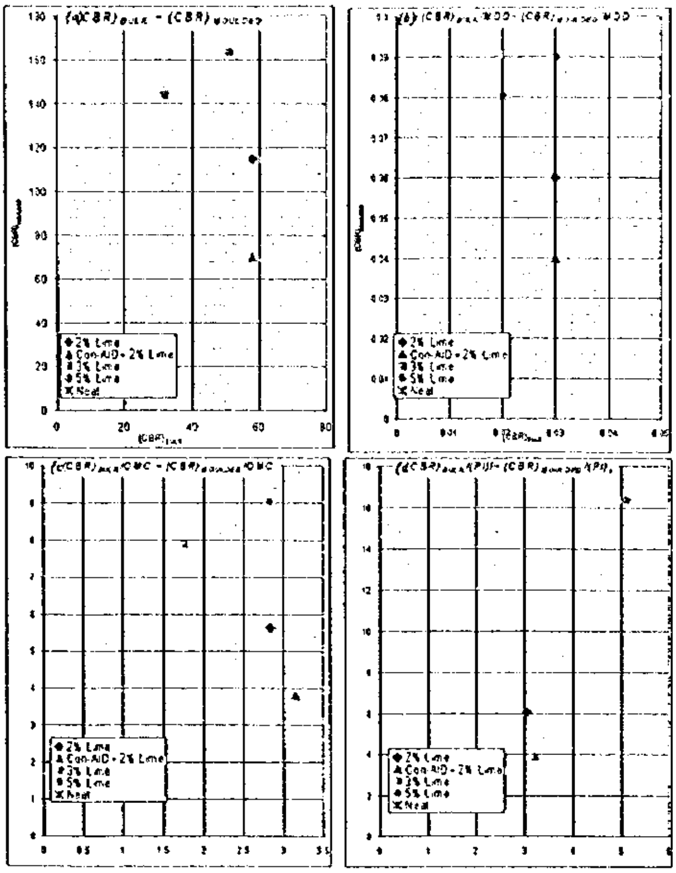


Fig. 5.3.4: Effect of Curing mode on CBR, CBR/MDD, CBR/OMC & CBR/(PI),

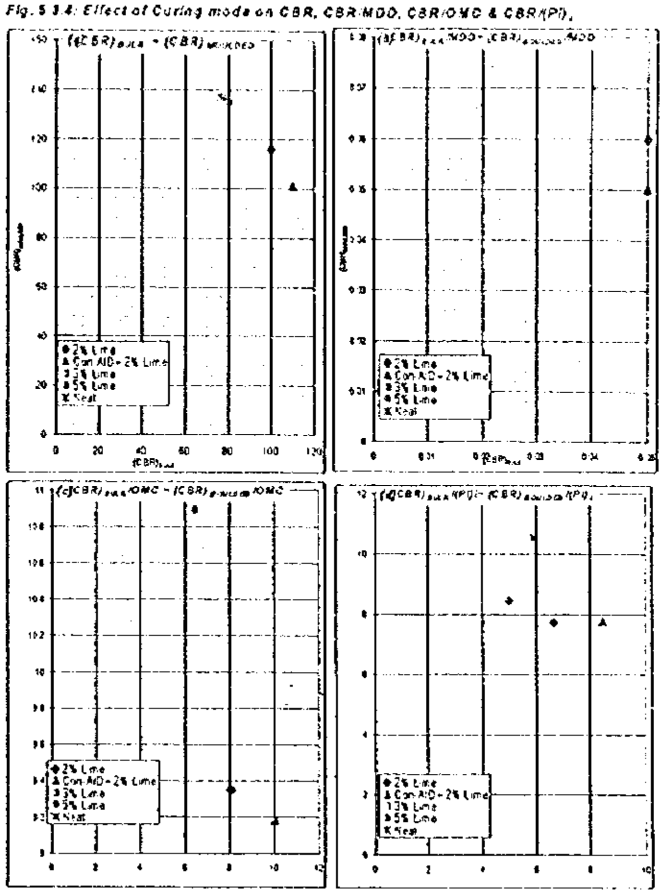


Fig. 5.3.5(a): Effect of curing period on CBR

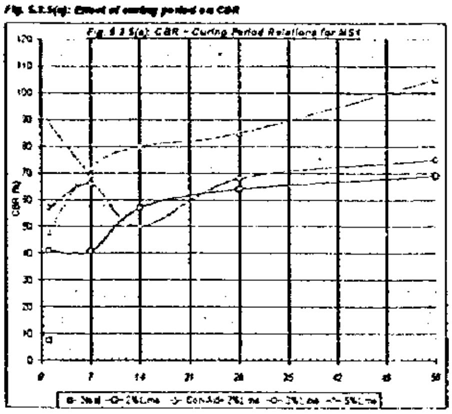


Fig. 5.3.5(b): Effect of curing period on CBR for MS2

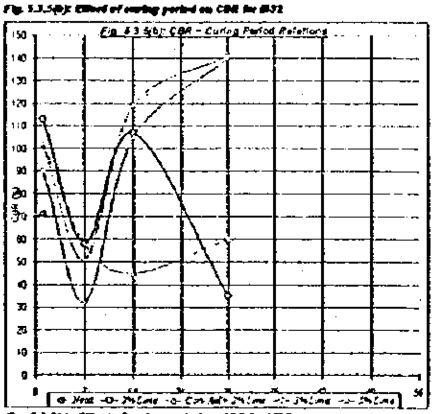


Fig. 5.3.5(c): Effect of curing period on CBR for MS3

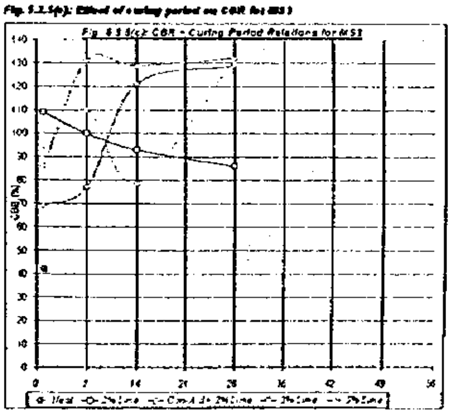


Fig. 5.3.5(d): Effect of curing period on CBR for MS4

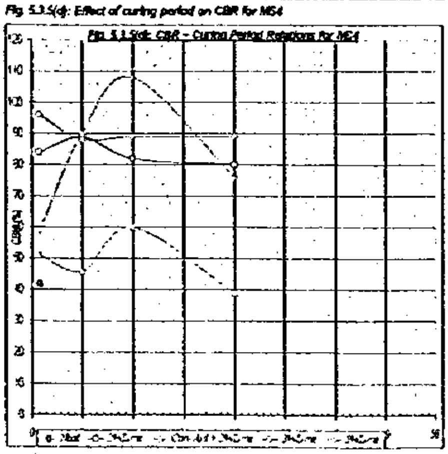
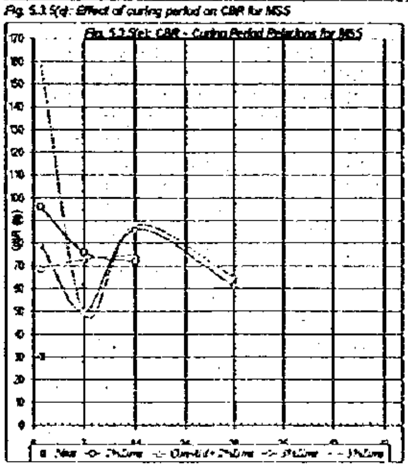
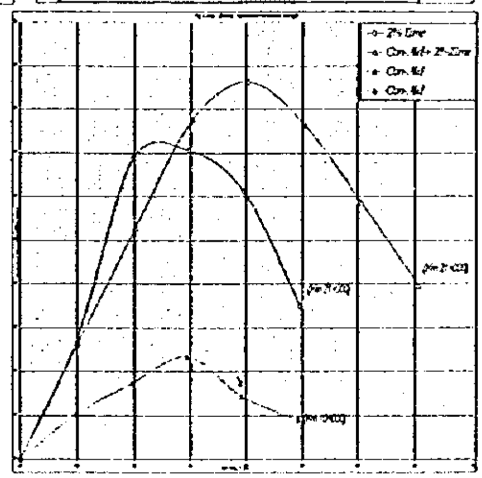


Fig. 5.3.5(e): Effect of curing period on CBR for MS5





- *Effect of Curing Period*

The characteristics of CBR in relation to curing period for the five materials (MS1~MS5) are shown in Figs. 5.3.5 (a) ~ (e). It can be derived from these results that: ~

i) For MS1 material, the treated soils stabilise after 14 days of cure with the Con-Aid +2% lime treated material yielding the highest CBR value of 105%.
ii) For MS2 the 3% and 5% lime treated materials yield the highest CBR values of 140 and 141% respectively.
iii) For materials sampled from MS3, the 2% lime treated material exhibits a consistent reduction in CBR strength with time while other treatments show strength development to almost a similar value of approx. 130% at 28 days cure.
iv) Materials from MS4 show no stabilisation in general.

These results imply that different material will have various responses to mode of treatment and period of curing.

5.3.2 *Unconfined Compression Strength (UCS)*

- *Effect of Treatment*

Fig. 5.3.6 (a) compares normalised stress strain $(q_u)_D/\{(qu)_{max}\}_s \sim \varepsilon_s$ characteristic curves of alignment Black Cotton Soils. Relations of the same depicting axial stress normalised the deformation modulus $(E_{50})_T$ $(q_u)_D\{(E_{50})_T\}_D$ from dynamic tests are shown in Fig. 5.3.6 (b). A comparison of these two figures indicates that:-

i) The increase of peak strength is drastic for lime treatments than pure Con-Aid.
ii) The initial and post-failure Stress~Strain behaviour of 2% lime and Con-Aid +2% lime treated materials is very similar in trend. This may imply that the composite effect of Con-Aid and lime responds actively to relative sliding at inter-particle contacts.
iii) Con-Aid may contribute to higher peak strength but lesser resistance to deformation. This can be confirmed from Fig. 5.3.6 (b) as well. It is clear from these results therefore that con~Aid and lime complement each other to induce different resistance components at different stages of progressive failure reciprocally.

Fig. 5.3.6(b): Effect of Treatment on Normalised Strength for 1 day bulk cured material

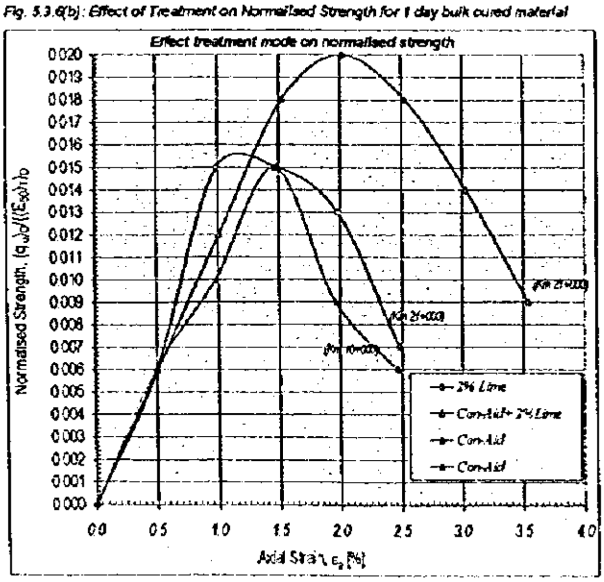
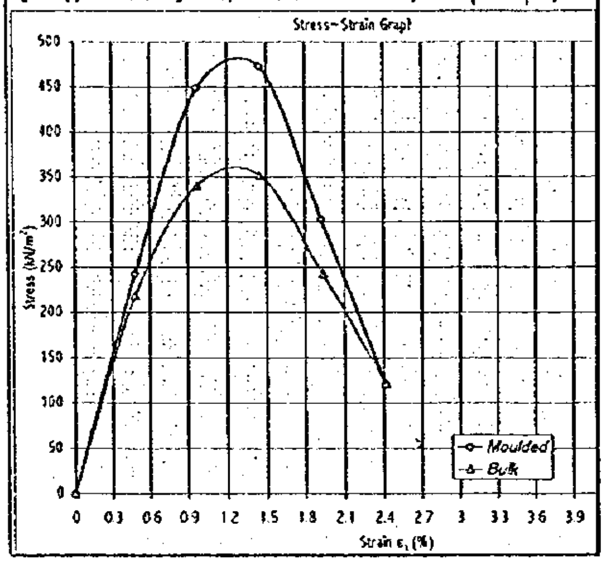


Fig. 5.3.7(a): Mode of curing effect (Bumala ~ Port Victoria Road) MS4 | Wet | 1 Day Cure



- *Effect of Mode of Curing*

As was seen in the preceding section 5.3.1, the mode of curing may play a vital role in the realisation of improved strength and other parameters upon treatment. In this section, this effect on the progressive failure characteristics of the bulk Vs. moulded specimens is analysed from Figs. 5.3.7 (a) and (b). Material treated with Con-Aid +2% lime exhibits higher peak strengths for the bulk cured materials for both MS4 and MS5.

This implies that for this treatment, better results are achieved by pre-compaction curing than post~compaction.

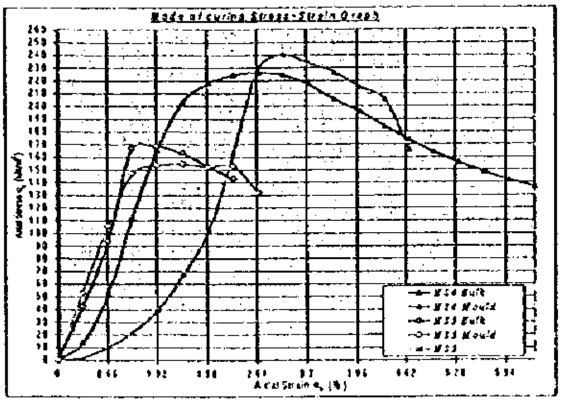


Fig. 5.3.7(b): Effect of curing mode

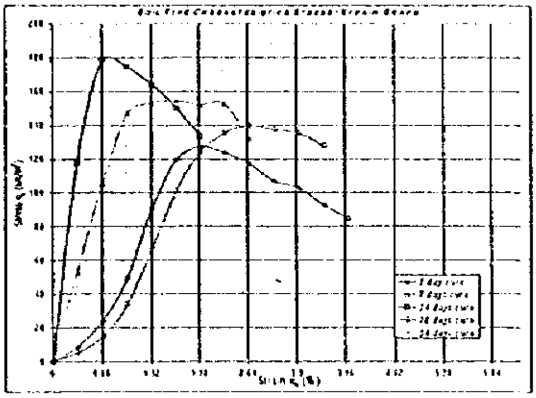
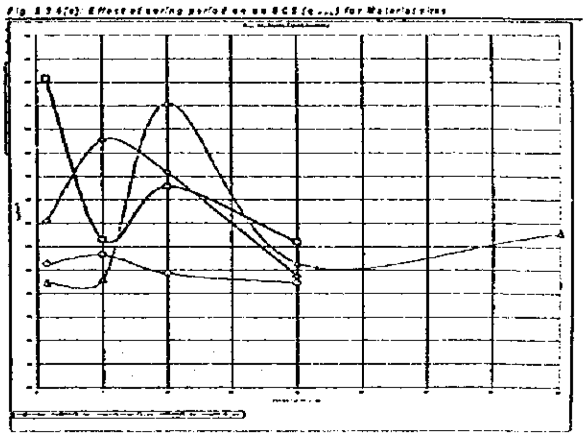
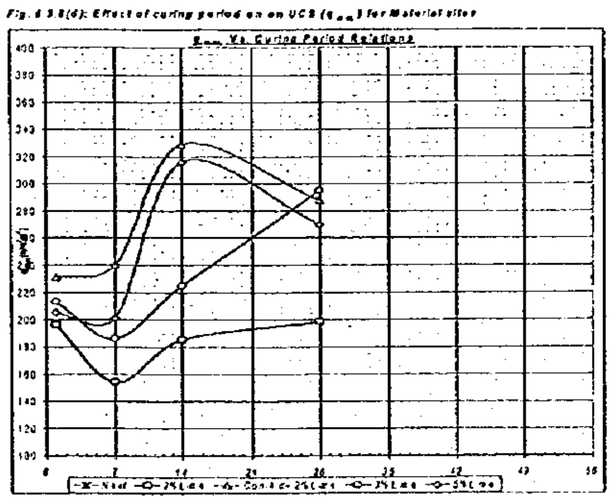
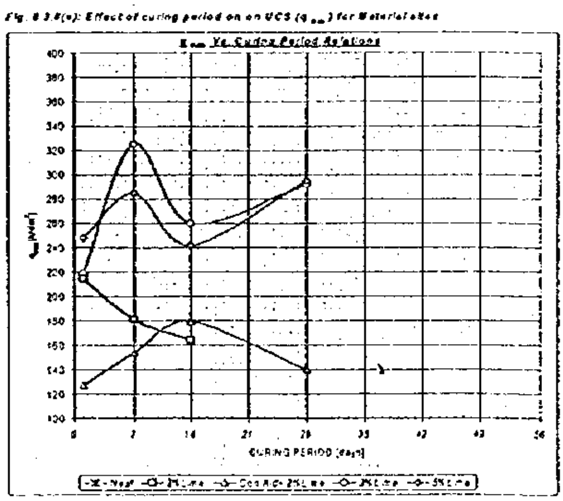


Fig. 5.3.8(a): Effect of curing period

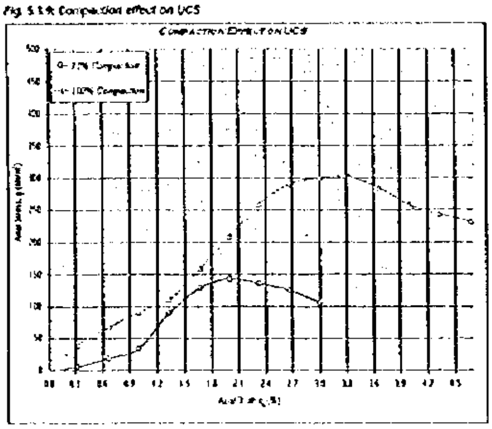


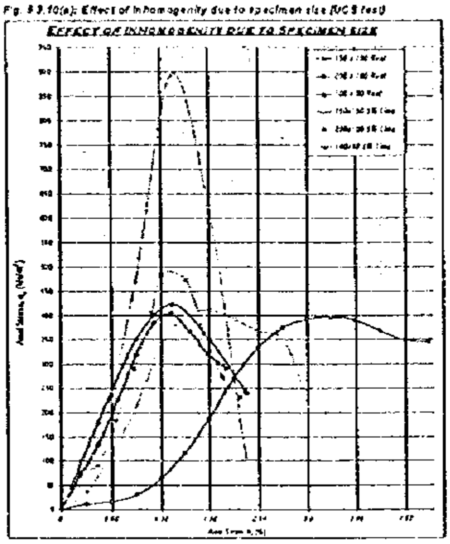


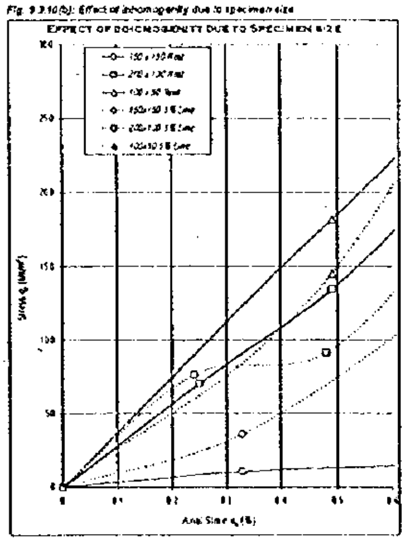


- *Effect of Curing Period*

Effect of curing period on the UCS of material sites is depicted in Figs. 5.3.8 (b) - (e). As in the case of the CBR tests it can be noted that all the materials respond differently to the period of curing. A curing period of not less than 28 days is recommended incase the material is cured under pre-compaction conditions. However, this study recommends that for optimum CBR and UCS results, the materials be compacted after 7 days of pre-compaction and cured thereafter.

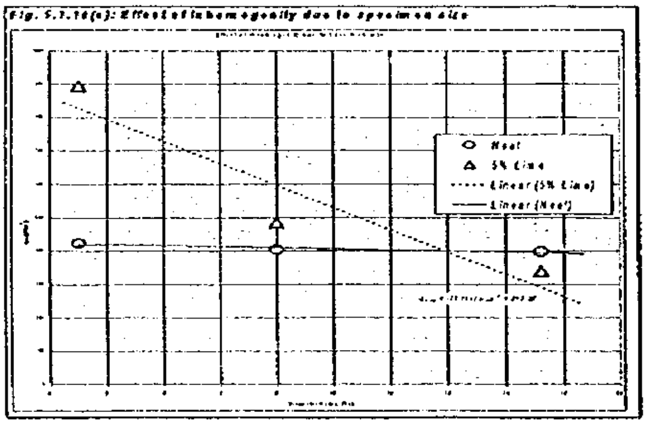


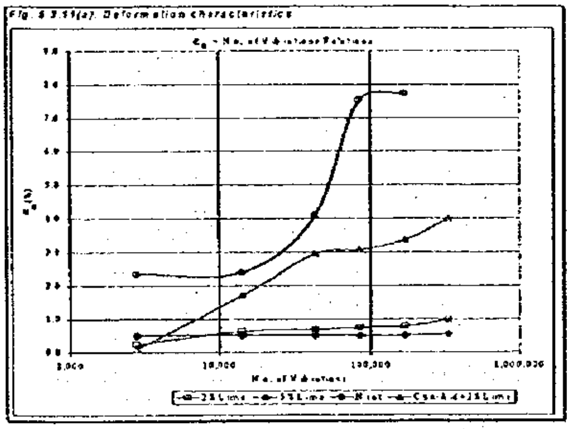




- *Effect of Compaction*

Specification and actual achievement of a certain level of compaction is always a subject of importance to the design engineer as well as the contractor. A series of tests were performed to study this effect for materials under different treatment. Typical Stress-Strain Curves for a Con-Aid treated materials compacted to 95% and 100% of MDD are shown in Fig. 5.3.9. It is observed that a 5% difference in compaction effort yields a difference in peak strength of approx. 53%.





- *Specimen Size Effect*

When performing experimental testing on a reconstituted material in the laboratory, it is important to mould a homogeneous specimen. Tests and analyses of the behaviour exhibited by material prepared in different moulds and sizes was carried out in order to establish a correction factor for this anomaly.

Figs. 5.3.10 (a) and (b) show the Stress-strain trends of specimens moulded in (ϕ=50, H=100], [ϕ=100, H=200] cylindrical [LxBxH = 150 x 150 x 150]mm, cubic moulds. Fig. 5.3.10 (a) and (b) show the overall and initial stress~strain behaviour of untreated and 5% treated material tested after 1day cure. Specimen size and mould effect are quite apparent. From these characteristics a correction Factor discussed in section 4.4 of this paper was developed.

5.3.3 *Mode of Loading Effect*

All the discussions in this section are based on UCS test results performed on ϕ=50mm, H=100mm cylindrical specimens which exhibited characteristics of the most homogeneous moulding properties. The soil tested was predominantly black cotton soil sampled from Bumala~Port Victoria alignment at km 21+000 and compacted by use of an electric vibrating hammer.

- *Deformation Characteristics*

For pavement structures, the simulation of cyclic vibrational loading is vital in determining the basic design parameters. To simulate the behaviour under such loading, a vibrating hammer was modified to impact a constant load (σ_D = 91.7 kN/m^2) to the cylindrical specimens for the various treatments and curing periods.

Deformation characteristics from tests designed to simulate compressive axle strain Vs. cumulative load axles as specified in the Road Design Manual are depicted in Figs. 5.3.11 (a) ~ (c) for 1, 7 and 14 days cure respectively. In general it can be observed that the untreated material, which failed after 168,000 vibrations, exhibits the highest deformation with increasing vibrations. For the treated materials, the rate of increase in deformation becomes more significant after 100,000 vibrations of loading. It is further observed that although straining is still apparent even after 1,000,000 vibrations, the treated materials do not fail under this dynamic loading.

The effect of curing period on plastic straining under dynamic loading is depicted in Fig. 5.3.11 (d). The general tendency is a reduction in plastic straining with enhanced curing period particularly 7 and 14 days cure for the treated materials.

Fig. 5.3.11(b): Deformation characteristics

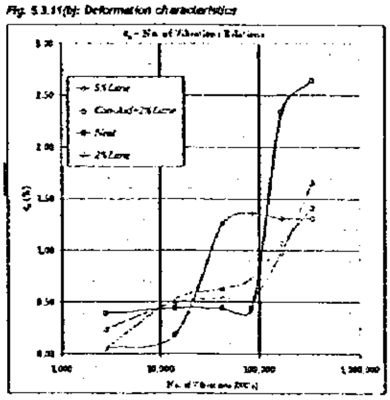


Fig. 5.3.11(c): Deformation charateristics

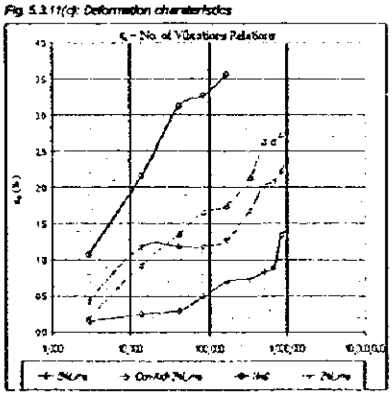
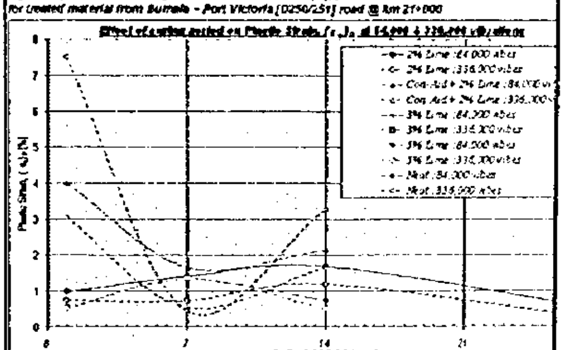


Fig. 5.3.11(d): Effect of curing period on Plastic strain, $(\varepsilon_v)_p$ at 84,000 & 336,000 vibrations for treated material from Bumala - Port Victoria [D250/251] road @ km 21+000

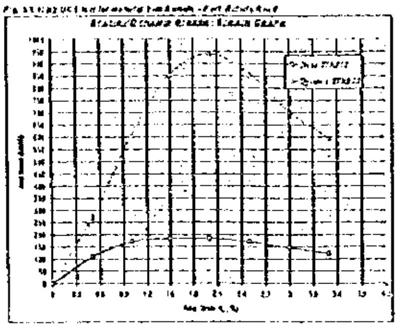


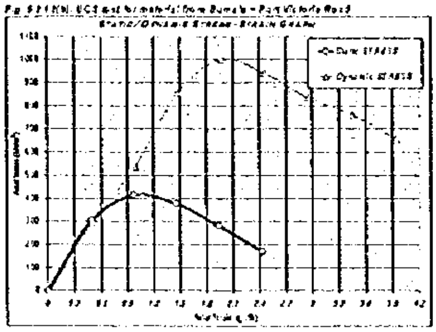
- *Static Vs. Dynamic*

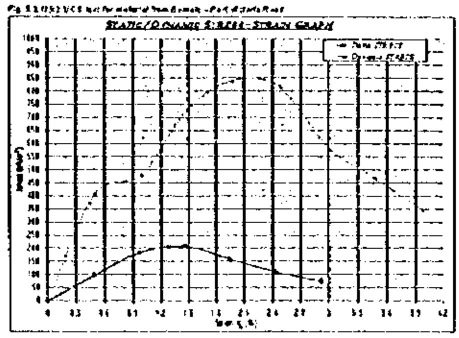
Figs. 5.3.12 (a) ~ (d) compare the stress-strain characteristics of untreated and treated 2% lime, con~Aid + 2% lime and 5% lime treated materials respectively. All specimens were tested after 7 days of bulk curing. The static to dynamic peak stress ratios and failure strains for the different treatments are shown in the following Table 5.3.1.

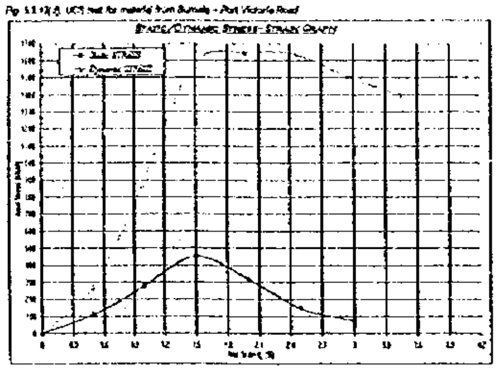
Table 5.3.1: Stress-strain parameters after 7 days cure.

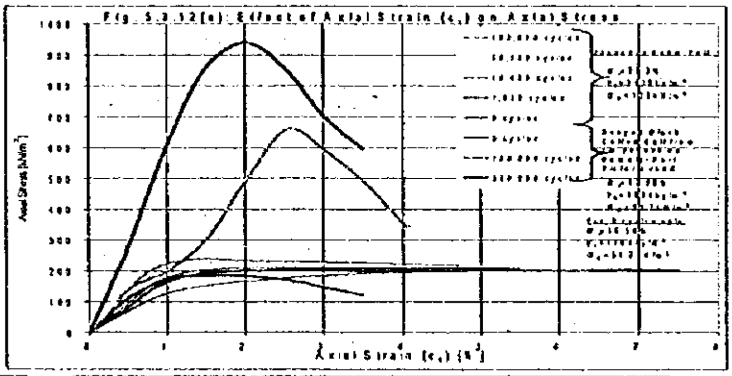
Mode of Treatment	$(q_{max})_S$ [kN/m^2]	$(q_{max})_D$ [kN/m^2]	$(q_{max})_S/(q_{max})_D$	$(\varepsilon_{af})_S$ [%]	$(\varepsilon_{af})_D$ [%]	$(\varepsilon_{af})_S/(\varepsilon_{af})_D$
2% Lime	441	1,000	0.41	0.97	1.97	0.49
Con-Aid+ 2% Lime	208	840	0.25	1.46	1.98	.74
5% Lime	318	1,646	0.19	2.00	1.97	1.02
Untreated	184	940	0.20	1.50	2.01	0.71

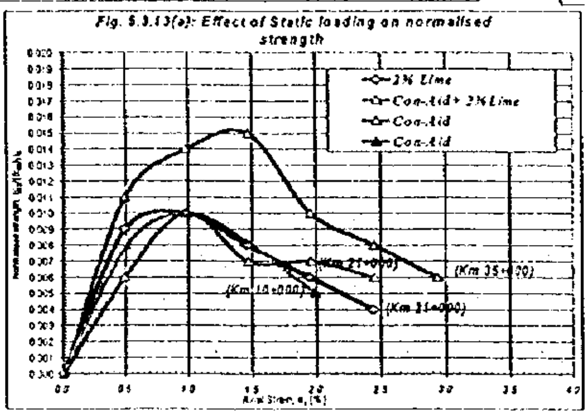


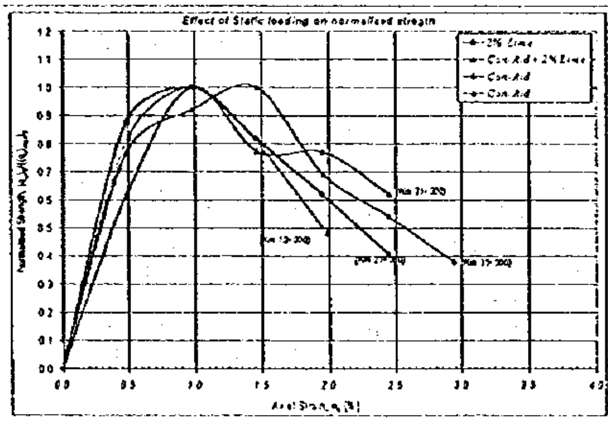








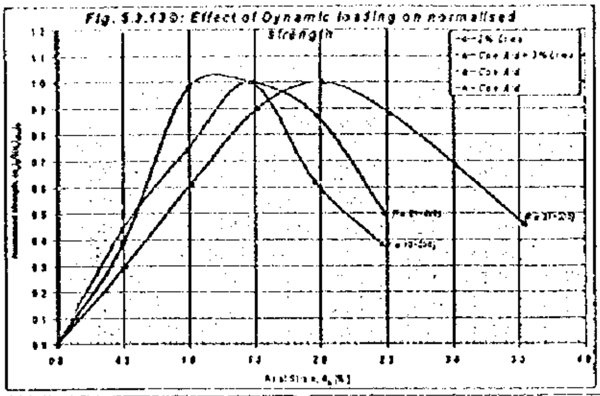


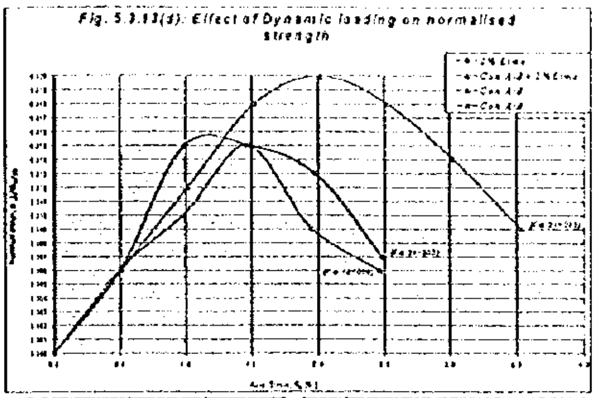


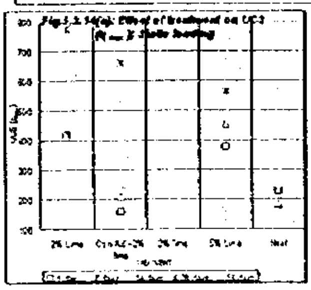
These results show conspicuously different Stress-strain behaviour.

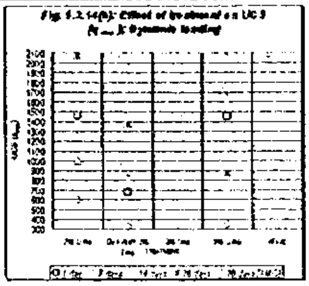
The influence of loading cycles portrayed in Fig. 5.3.12 (e) compares the Stress-Strain characteristics of Japanese and Kenyan soils. This figure shows that, notwithstanding material type, the influence of loading cycles becomes increasingly dominant after 100,000 cycles of loading whereby deformation resistance and peak strength increase significantly.

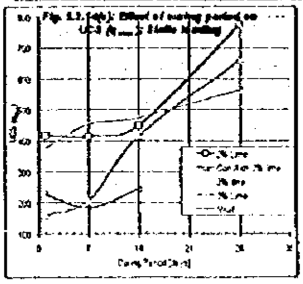
A comparison of the normalised static Vs. dynamic stress-strain characteristics from Figs. 5.3.13 (a) - (d) indicates that treatment becomes increasingly effective for specimens subjected to dynamic loading. In Figs. 5.3.14 (a) and (b), the effect of treatment on statically and dynamically loaded specimens can be observed. The 2% lime treated specimens exhibit the highest strengths after 28 days of cure for both static and dynamic peak strengths.

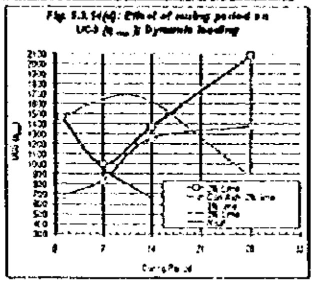










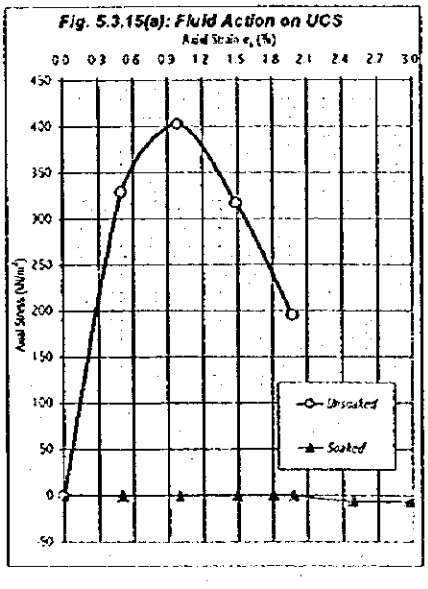


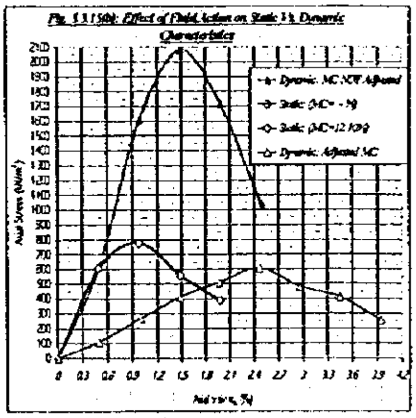
The effect of curing period on the specimens subjected to the two modes of loading is examined in Figs. 5.3.14 (c) and (d). It can be noted that whereas the tendency is for the peak strength to increase with enhanced curing period for the statically loaded specimens, no clear trend can be seen for the dynamically loaded material other than the one treated with Con-Aid + 2% lime.

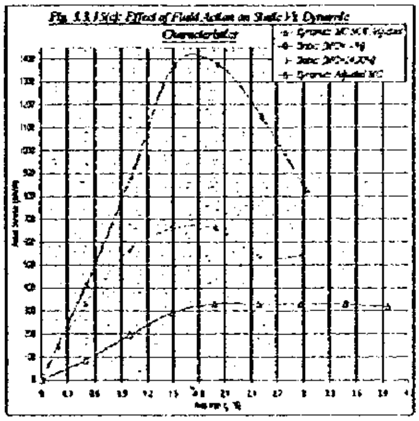
These results show that the 2% lime treatment is most effective both in strength development with curing period.

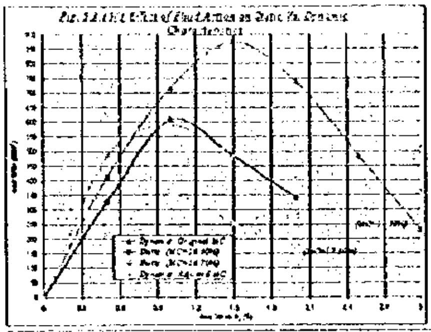
- *Effect of Fluid Action*

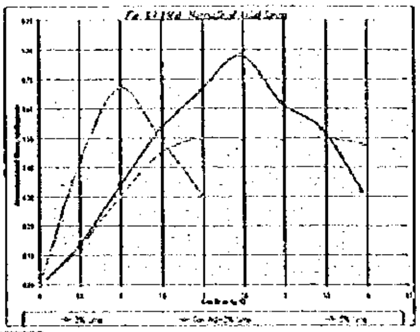
Under this topic, the effects of moisture-suction variations on the strength, stress-strain and deformation characteristics are studied. Fig. 5.3.15(a) shows the comparison of the stress-strain behaviour of a specimen which was soaked to maximum swell and an unsoaked one. The effect of increasing the moisture content by 1.8 times decreases the strength drastically $[(q_{max})_{soaked}/(q_{max})_{soacked} = 0.05\%]$ and to destroy its structure to a state of collapse.

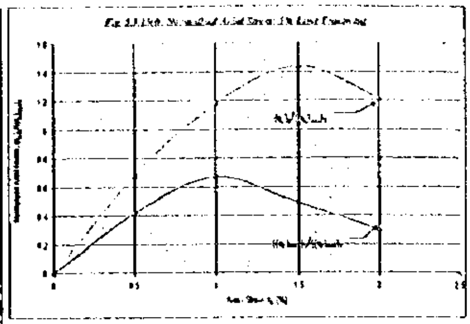


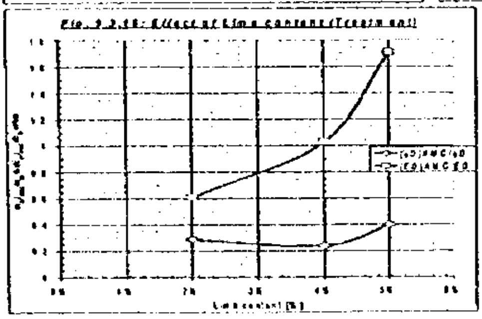












By applying controlled water infiltration to increase the moisture content of an initially dynamically loaded specimen the effect of moisture suction variation was further investigated. Figs. 5.3.15 (b) - (d) compares the specimens subjected to Adjusted Moisture Content (AMC) to those moulding MC. Details of the testing method are described in the Geotechnical Engineering, Material Testing Analyses Report of October 1999.

These figures show that in all cases, the AMC specimens are much weaker and exhibit less brittle characteristics than their counterparts implying that even a slight change in water content through mechanical infiltration affects the intrinsic structure of the specimen.

Fig. 5.3.15 (e) shows the variation in behaviour of treated material subjected to fluid infiltration. It can be clearly seen that the materials behave quite differently indicating their structures are different

The normalised axial stress ~ axial strain curves in Fig. 5.3.15 (e) show the significant effects of fluid action to a geomaterial. In Fig. 5.3.16 the variation of lime content with AMC and MMC (Moulding Moisture Content) Stress and Modulus ratios is represented. This figure shows that the modulus of deformation subjected to water~suction variations responds better to the increase in lime content than the peak strength does. This means that further treatment of a material subjected to increase in MC may recover its structure.

5.4 *Modulus of Deformation*

The effect of treatment on the modulus of deformation for different periods of curing and modes of loading is summarised in Fig. 5.4.1(a)~(i). The following observations can be made from these figures [$(E_{50})_T$: experimental E_{50} value, $(E_{50})_C$: calculated value, $(E_{50})_{0.5}$ value at $\varepsilon_a = 0.5\%$].

i) The variations between the moduli are time and treatment dependent.
ii) The moduli of deformation of the Con~Aid +2% lime are more consistent and less sensitive to factors of change than the lime treated material.
iii) Dynamic moduli are much higher than static moduli. This implies that these values do not represent the true elastic moduli.

Fig. 5.4.1(a)

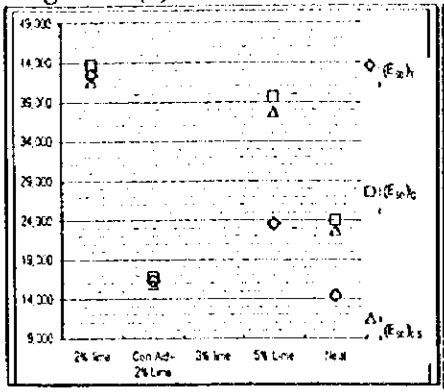


Fig. 5.4.1(b)

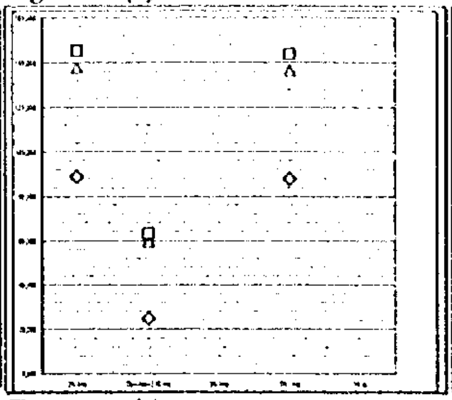


Fig. 5.4.1(c)

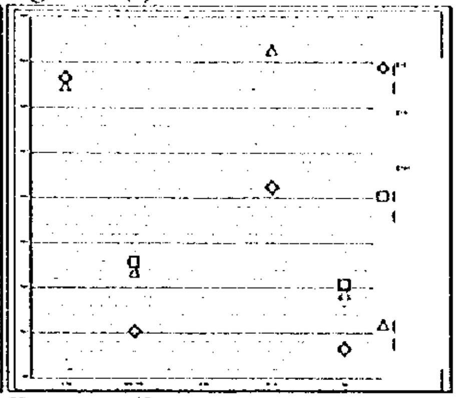


Fig. 5.4.1(d)

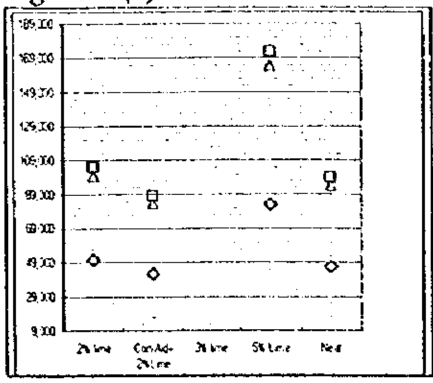


Fig. 5.4.1(e)

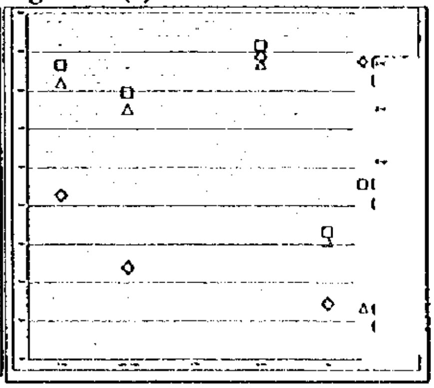


Fig. 5.4.1(f)

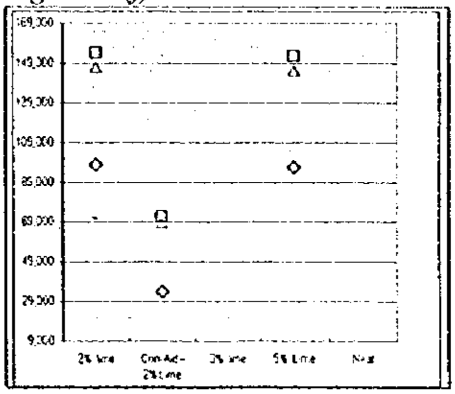


Fig. 5.4.1(g)

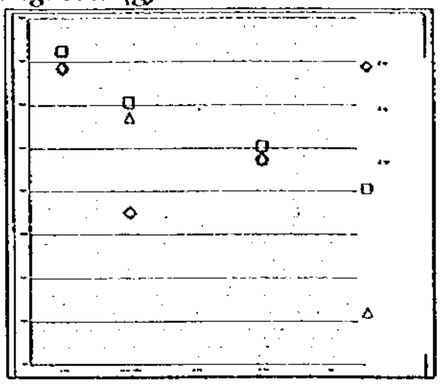


Fig. 5.4.1(h)

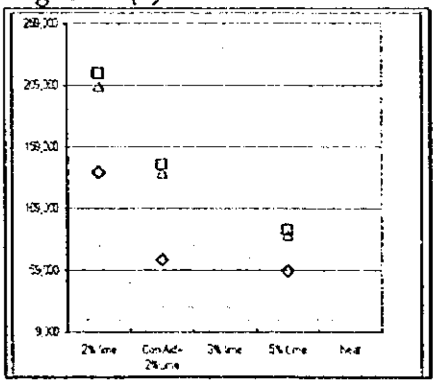
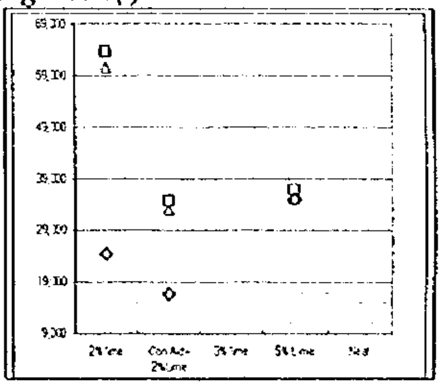


Fig. 5.4.1(i)



The results indicate the necessity to develop a method of estimating the approximate linear elastic modulus.

The effect of loading mode on the moduli of deformation can be observed from the plots in Figs. 5.4.2(a)~(f) for specimens cured for 7 days and Figs. 5.4.3(a)~ (f) for those cured for 14 days. These figures show that the variations to be time dependent and:-

i) the dynamic moduli are higher than the static ones for all treatments.
ii) Dynamic loading effect is to lower moisture content notwithstanding the mode of treatment.
iii) Dynamically loaded ground has higher sensitivity factors particularly for lime treated materials.

The variations with curing period of E_{max} and $(\varepsilon_a)_{ELS}$ determined by applying equations 4.3.3 and 4.3.4 respectively are shown in Figs. 5.4.4(a) and (b) for MS4 material and Figs. 5.4.4(c) and (d) for MS5 material.

In general these figures show erratic E_{max} and $(\varepsilon_a)_{ELS\,R}$ behaviour with time for both materials unlike the q_{max} which tended to stabilise after a certain period of curing. It may take longer for the deformation associated structure to recover.

Fig. 5.4.2: Effect of loading mode on modulus parameters for material on Bumala~PortVictoria road @ km21+000 7 DAY CURE

Parameter / Treatment	q_u (kN/m²)	C_u (kN/m²)	$(\varepsilon_a)_{max}$ (%)	$(\varepsilon_a)_{50}$ (%)	$(E_{50})_f$ (kN/m²)	E_C (kN/m²)	$(E_{50})_{0.5}$ (kN/m²)	MC [%]	$S_t=E_C/(E_{50})_f$	Hours of Vibration	
2% lime	1,000	500	1.97	0.99	50,505	105,000	100,000	12.96	2.08	6.0	LOADING MODE: DYNAMIC
Con-Aid+ 2%Lime	840	420	1.98	0.99	42,424	88,200	84,000	15.82	2.08	2.0	
3% lime									#DIV/0!		
5% Lime	1,646	823	1.97	0.99	83,131	172,830	164,600	15.00	2.08	2.0	
Neat	940	470	2.01	1.01	46,535	98,700	94,000	12.80	2.12	1.0	
2% lime	414	207	0.97	0.49	42,265	4,349	41,420	15.42	0.10		LOADING MODE: STATIC
Con-Aid+ 2%Lime	208	104	1.46	0.73	14,247	21,840	20,800	18.74	1.53		
3% lime									#DIV/0!		
5% Lime	453	227	1.50	0.75	30,200	4,757	45,300	17.50	0.16		
Neat	184	92	1.50	0.75	12,267	19,320	18,400	16.50	1.57		

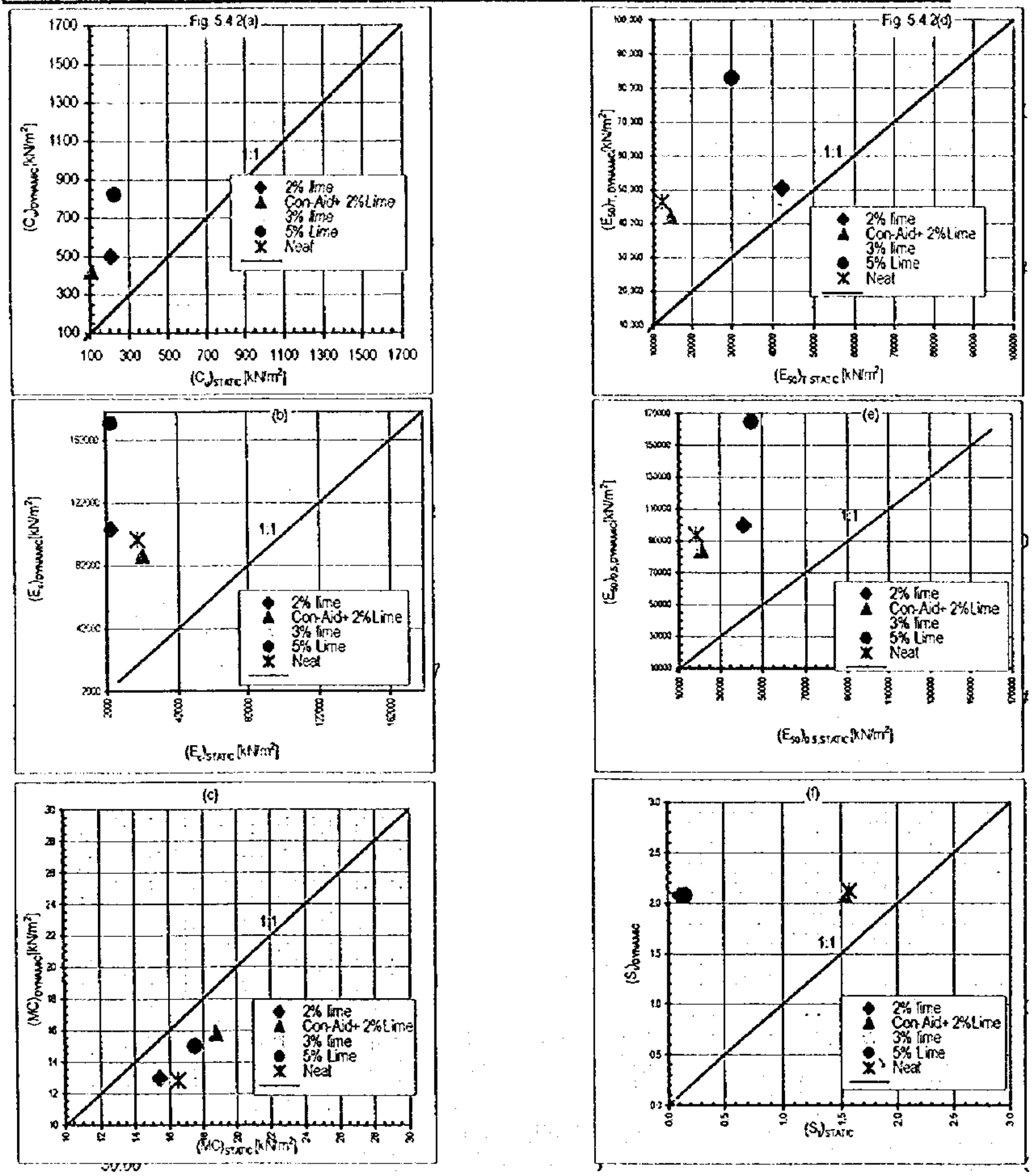
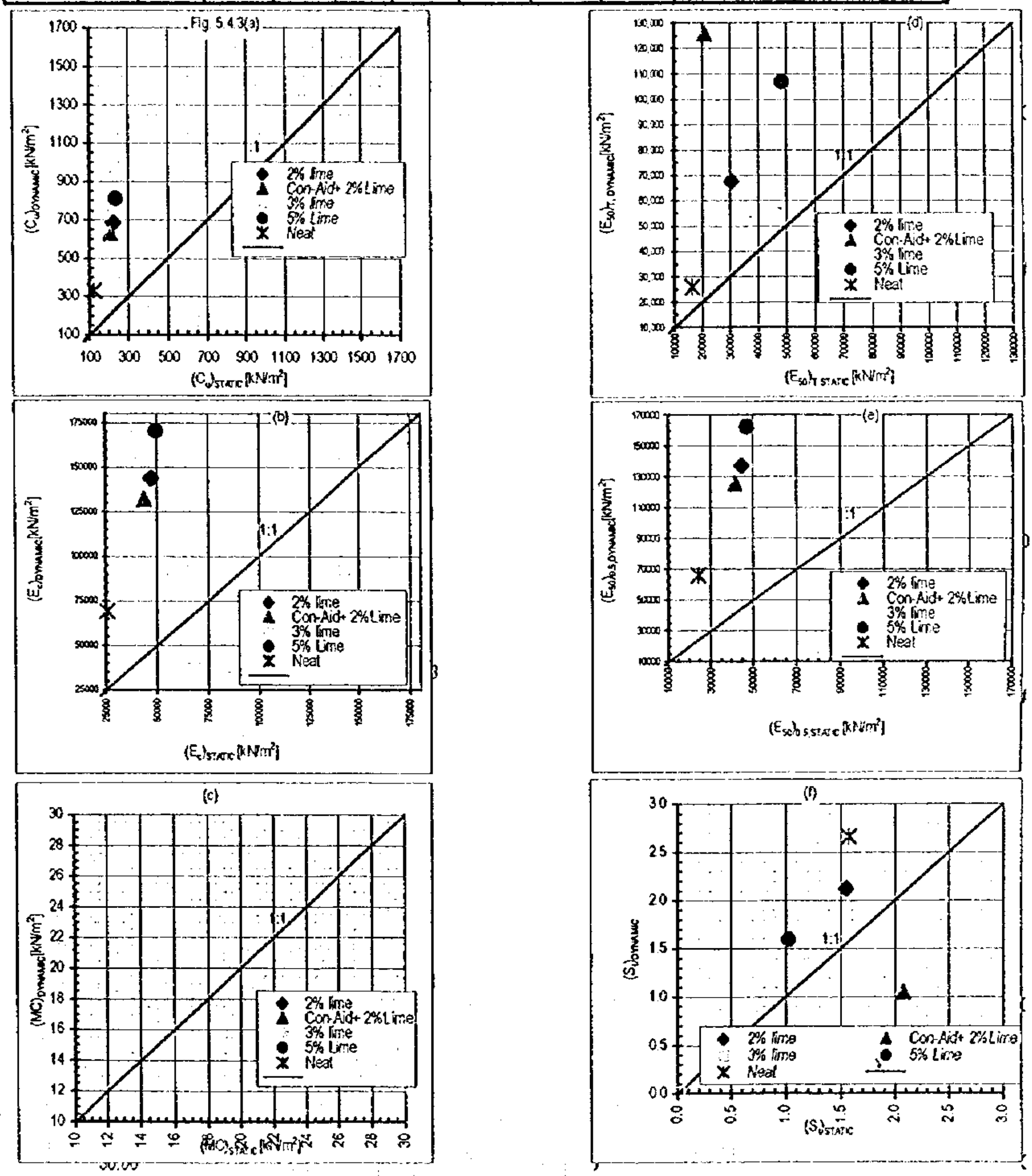


Fig. 5.4.3: Effect of loading mode on modulus parameters for material on Bumala-PortVictoria road @ km21+000 14 DAY CURE

Parameter / Treatment	q_u (kN/m²)	C_u (kN/m²)	$(\varepsilon_a)_{max}$ (%)	$(\varepsilon_a)_{50}$ (%)	$(E_{50})_T$ (kN/m²)	E_C (kN/m²)	$(E_{50})_{0.5}$ (kN/m²)	MC [%]	$S_t=E_C/(E_{50})_T$	Hours of Vibration	
2% lime	1,370	685	2.02	1.01	67,822	143,850	137,000		2.12	6.0	LOADING MODE: DYNAMIC
Con-Aid+ 2%Lime	1,258	629	1.00	1.00	125,800	132,090	125,800		1.05	6.0	
3% lime									#DIV/0!		
5% Lime	1,622	811	1.51	0.76	106,711	170,310	162,200		1.60	6.0	
Neat	660	330	2.53	1.27	25,984	69,300	66,000		2.67	1.0	
2% lime	450	225	1.48	0.74	30,405	47,250	45,000		1.55		LOADING MODE: STATIC
Con-Aid+ 2%Lime	416	208	1.98	0.99	21,010	43,680	41,600		2.08		
3% lime									#DIV/0!		
5% Lime	474	237	0.97	0.49	48,367	49,770	47,400		1.03		
Neat	244	122	1.49	0.75	16,267	25,620	24,400	16.60	1.57		



5.5 Swell Behaviour

The importance of swell behaviour in terms of moisture-suction variation cannot be over emphasised particularly for fine-grained materials with expansive characteristics. In this section, possible methods to contain swell are considered by analysing its behaviour when subjected to various conditions.

- *Effect of Treatment on MC Variations with Time*

  Fig. 5.5.1(a) shows the variation of moisture content with time for material treated with three different lime contents. It can be seen that there is hardly any variation with treatment over the whole period of monitoring.

Fig. 5.4.4(a)&(b): Effect of curing period on E & (ε) for Material Site No. 4 on Bumala - Port Victoria

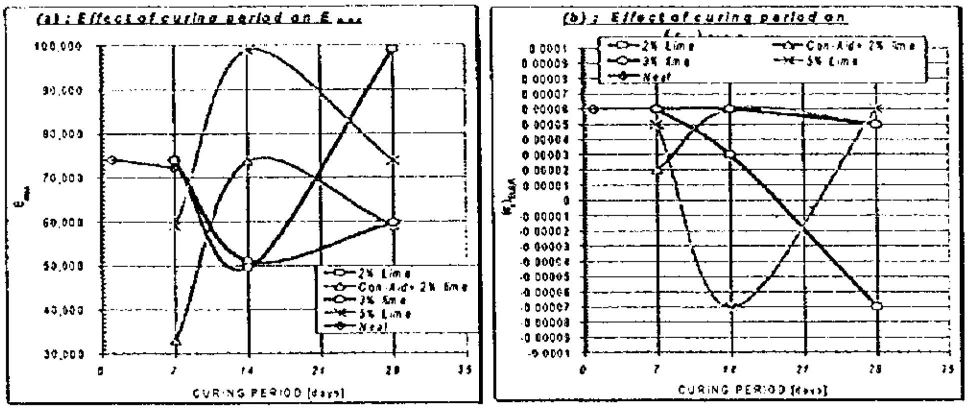
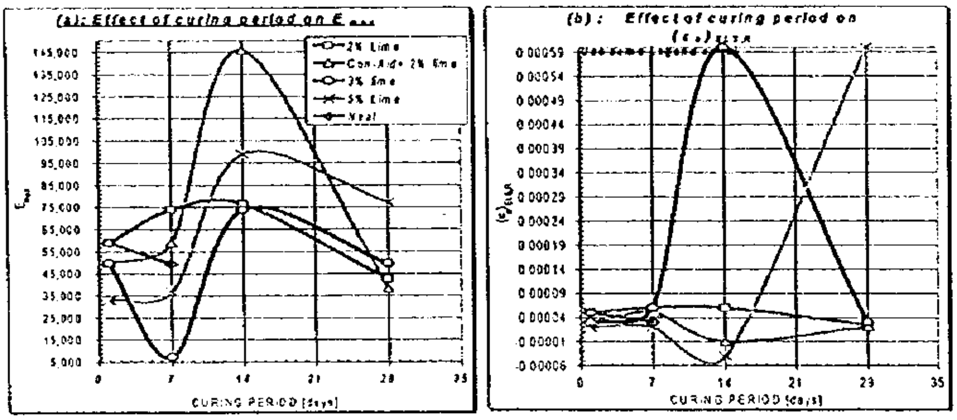


Fig. 5.44(c)&(d): Effect of curing period on E & (ε) for Material Site No. 5 on Bumala - Port Victoria



- *Effect of Treatment*

  It can be derived from Fig. 5.5.1(b) that although the magnitude of swell varies with treatment, the general swell vs. soaking period is quite similar in trend notwithstanding treatment. On the basis of this observation therefore, a method of estimating the ultimate maximum swell based on the component of initial rate of swell is proposed in this study (ref. to section 4.5). It is established that the mode of treatment in containing swell.

- *Effect of Surcharge Pressure*

  The effect of surcharge pressure in controlling the swell behaviour is analysed from Figs. 5.5.1(c)~(g). These figures show that: ~

i) The effect of surcharge on swell behaviour varies with mode of treatment.

ii) For pure Con-Aid treated material, increase in surcharge pressure reduces the amount of swell almost linearly.

However, for the 2% lime and Con~Aid +2% lime treated materials, the tendency is to reduce in the initial stage of increase in surcharge pressure and to reach a limiting state whereby it starts to increase prior to decreasing under surcharge pressures greater than 6 kN/m^2.

iii) It may appear that at low surcharge pressures the swell behaviour is insensitive to curing period. However, as it can be seen for the Con~Aid +2% lime treated material, at higher surcharge pressures the material cured for 7 days shows a greater reduction in swell in comparison to 1 day.

iv) It is interesting to note that the two Con~Aid + 2% curves disect at two locations. This confirms the fact that the characteristic of Con~Aid is to reduce the amount of swell constantly with increasing surcharge.

These results show that surcharge pressure may be employed in controlling the magnitude and characteristics of swell

Fig. 5.5.1(a): Daily Moisture Content Monitoring

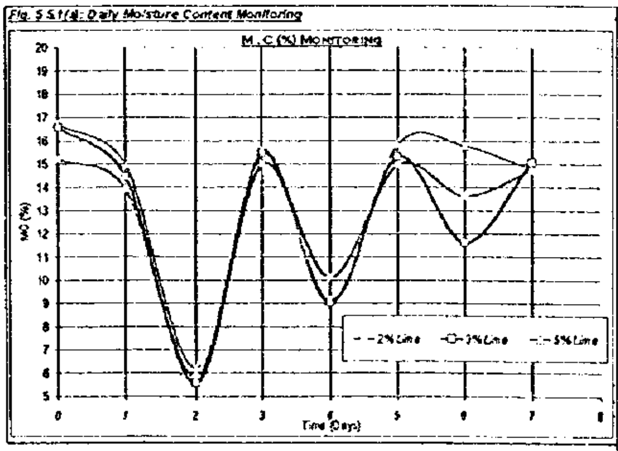
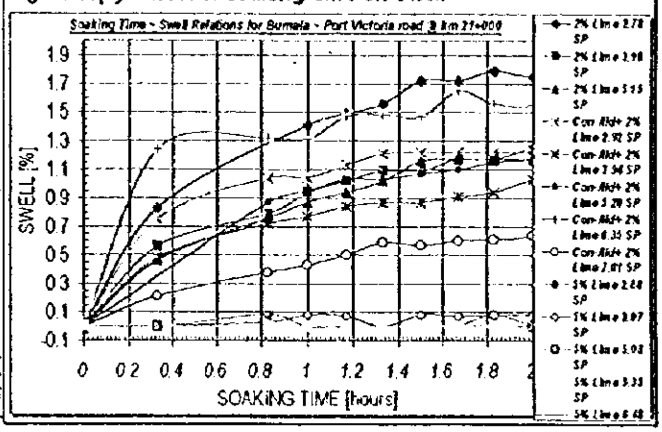


Fig. 5.5.1(b): Effect of soaking time on Swell



- *Effect of Loading Mode*

In Section 5.3.3 it was observed that dynamic loading had a tendency of reducing the moisture content and that this reduction was influenced by the number of loading cycles.

This topic focuces on investigating whether dynamic loading influences swell behaviour. From Fig. 5.5.1 (d) it can be seen that the initial rate of swell and maximum swell are higher for dynamically loaded specimens when comparing the behaviour at similar surcharge pressures. This behaviour is reciprocal to that of moisture.

- *Combined Effects of Compaction, Surcharge Pressure, Mode of loading, Monotonic Cyclic Loading on Swell*

The above combined effects were investigated by applying a comprehensive testing method modified in this study and described in detail in the Geotechnical Engineering, Materials Testing Analyses Report of Oct. 1999. Some of the typical results of these tests were presented in Fig. 5.5.1(d)~(g). The following derivations can be made from these figures: -

(i) Higher Compaction effort and dynamic loading increase the initial rate of swell and maximum swell values.

(ii) Notwithstanding the effect of loading mode and surcharge pressure, all specimens exhibit a tendency towards maximum swell after approximately 7.5 hours of soaking.

(ii) The initial rate of swell is only sensitive to Surcharge Pressure but not to mode of loading

(iii) Notwithstanding the various effects, it is observed that the initial rate of swell is a major contributing factor to the maximum swell.

(iv) Once the specimens reach the maximum swell conditions, they become virtually insensitive to the load/unload/reload cycles hence swell is virtually constant and does not increase with soaking period.

This implies that once a material achieves the maximum swell, it is no longer susceptible to swell under such mechanical conditions as investigated in this study.

From the foregoing discussions it can therefore be concluded that the most important factor to control swell behaviour is the initial rate of swell.

Fig. 5.5.1(c): Effect of Surcharge Pressure on Normalised Swell

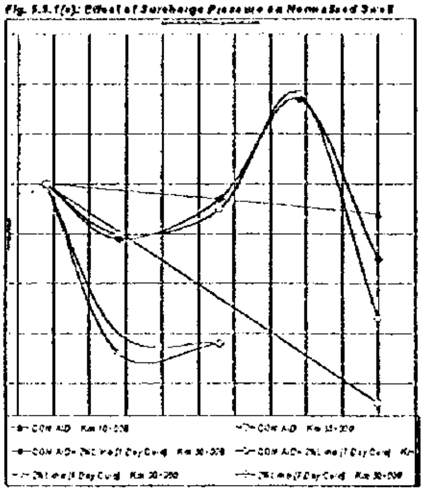


Fig. 5.5.1(d): Effect of compaction and surcharge pressure on SWELL

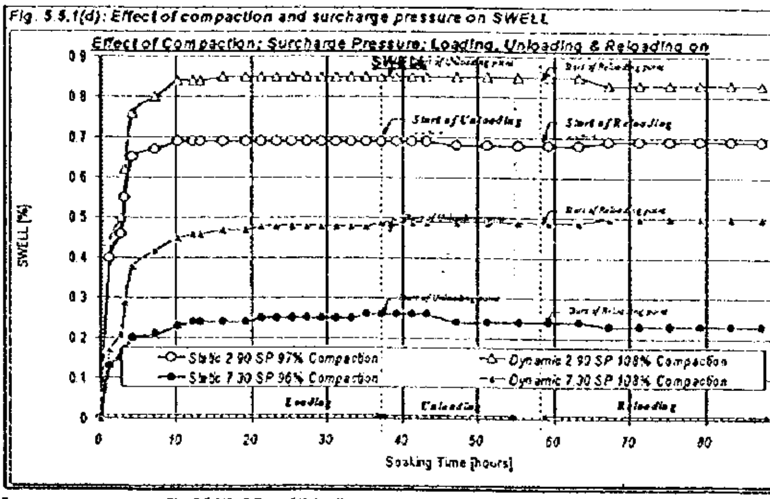


Fig. 5.5.1(e): Effect of compaction and surcharge pressure on SWELL First Loading

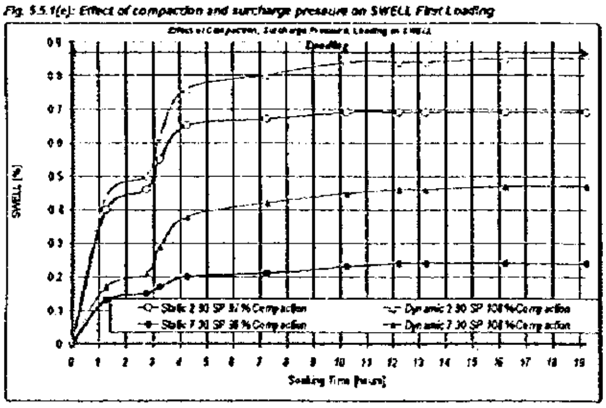


Fig. 5.5.1(f): Effect of Unloading

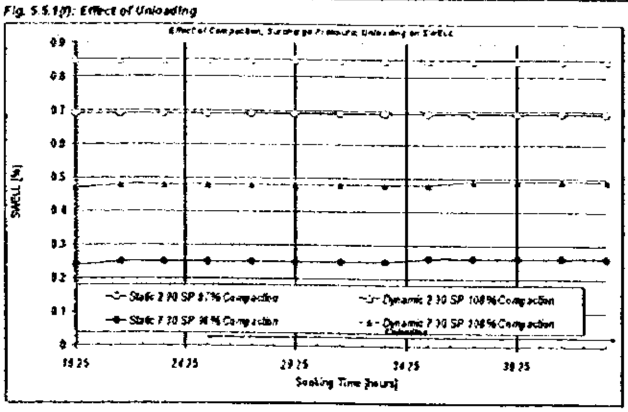


Fig. 5.5.1(g): Effect of Reloading

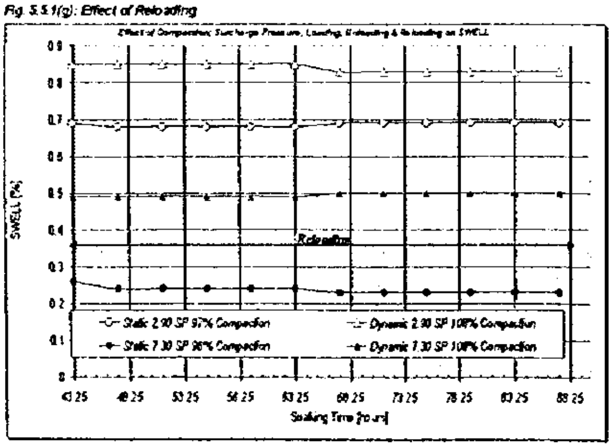
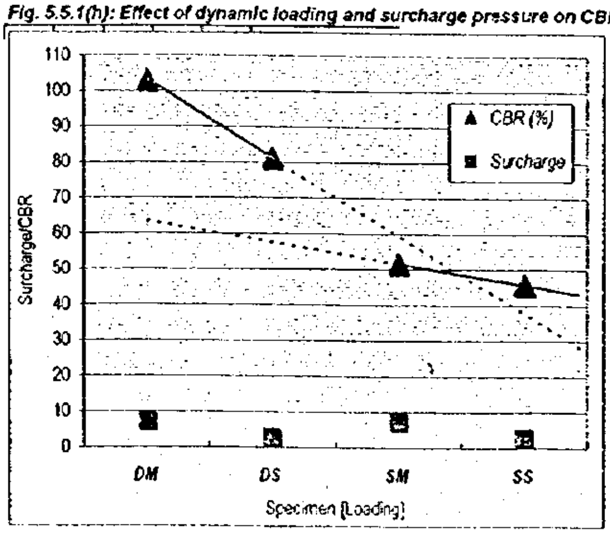


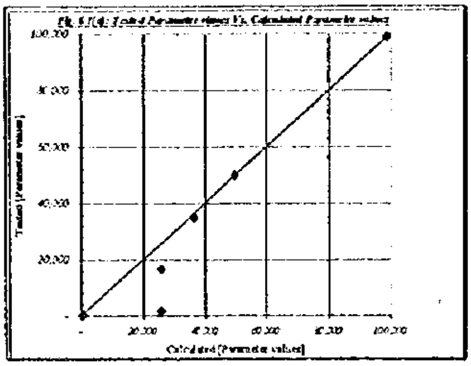
Fig. 5.5.1(h): Effect of dynamic loading and surcharge pressure on CBR

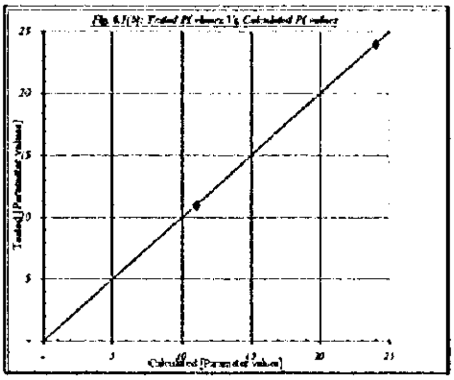


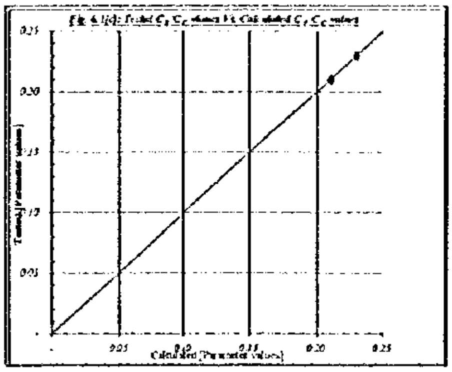
6. Characterisation Of The Geomaterials Tested

6.1 Theoretical Vs. Experimental Parameters

Figs. 6.1(a)~(c) show the relation between some of the parameters determined experimentally Vs. those calculated using the new equations proposed in this study (ref. Section 4). As it can be seen, there is an extremely good agreement between the tested and the calculated values.







6.2 Generalised State Equations for further R & D and Design Purposes

This study has demonstrated the importance of developing Generalised State Equations which would assist in not only guiding the Design Engineer in case insufficient or lack of ability to determine complex data, but also in facilitating the establishment of a databank for enhancing R&D activities in this field.

7. Practical Application Of Test Parameters For Design Purposes

7.1 Based on Kenya Road Design Manual Part III

Figs. 7.1.1(a) and (b) show the CBR Vs. E_{max} and CBR Vs. E_{50} data determined in this study from alignment soils in relation to the Subgrade CBR Vs. Subgrade Modulus which is in accordance with the specification from the Kenya Road Design Manual. The data that plots within the vicinity of Line of Ideal Relation qualifies the material to be used for the class indicated.

Fig. 7.1(a): Alignment soils of WKRRIS determined data: CBR Vs. Emax

Ref	Soil Class	CBR Median [%]	Subgrade Moduli [kN/m2]
RDM	S1	3.5	15,100
RDM	S2	7.5	50,100
RDM	S3	10	65,100
RDM	S4	14	90,100
RDM	S5	22.5	125,100
RDM	S6	>30	250,100
km [illegible]	Con-Aid	2	98,751
km [illegible]	Con-Aid	3	66,971

*Note: RDM is Kenya Road Design
Data taken from p.6.1 & 8.1

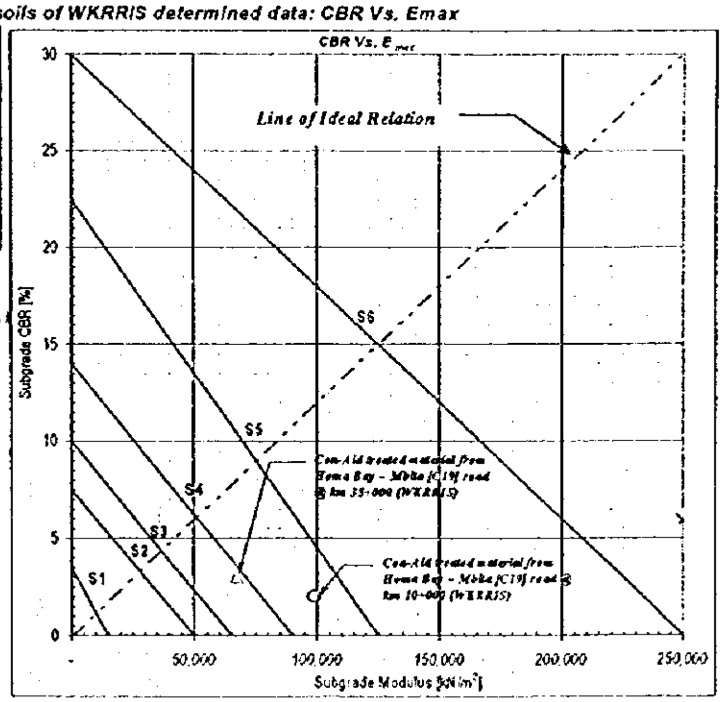
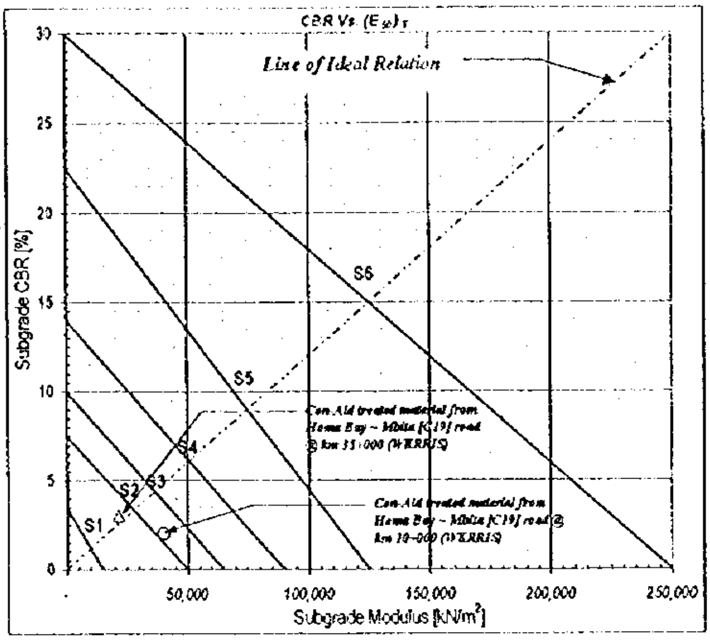


Fig. 7.1(b): RDM & WKRRIS Subgrade material CBR Vs. $(E_{50})_T$ relation

Ref	Soil Class	CBR Median [%]	Subgrade Moduli [kN/m2]
RDM	S1	3.5	15,100
RDM	S2	7.5	50,100
RDM	S3	10	65,100
RDM	S4	14	80,100
RDM	S5	22.5	125,100
RDM	S6	>30	250,100
km 10+000	Con-Aid	2	40,200
km 35+00	Con-Aid	3	21,450

Note: RDM is Kenya Road Design Manual Data taken from p.8 1.6.8.4



Similar plots for Subbase material are shown in Figs. 7.1.2 (a) and (b). The E_{max} in these figures was calculated using equation 4.3.1 proposed in this study. In terms of Modulus of elasticity, most materials do not seem to meet the requirements. However, it must be noted that the issue of bedding errors and system compliance was not taken into account. Further testing to establish the corresponding correction factors is necessary. A further comparison of these relations shows that the $(E_{50})_T$ Modulus is much lower than the standards of modulus specified by the RDM in both cases. The use of such a parameter in design would therefore be misleading since it would necessitate, for example, the use of a high safety factor which would escalate the cost of the structure. This demonstrates the importance of precise determination of design parameters.

Fig. 7.1.2(a): RDM & WKRRI Study area LIME improved material for Sub base, CBR Vs. moduli, E_{max}

Ref	Proposed Sub-base Material (treatment)	CBR [%]	Sub-base E_{max} [kN/m2]
RDM	SB1	60	300,000
RDM	Sb2	128	999,000
RDM	SB3	170	1,229,000
RDM	base	238	1,696,000
RDM	base	383	2,340,000
RDM	base	509	4,680,000
MS4 (7 day	2% Lime	89	187,980
MS4 (7 day	Con-Aid+ 2% Lime	46	83,757
MS4 (7 day	3% Lime	89	187,759
MS4 (7 day	5% Lime	90	149,687
MS5 (7 day	2% Lime	75	187,790
MS5 (7 day	Con-Aid+ 2% Lime	73	149,939
MS5 (7 day	3% Lime	50	18,735
MS5 (7 day	5% Lime	49	93,590

MS denotes Material Site for West Kenya Rural Roads Improvement Study area
Note: RDM is Kenya Road Design Manual Data taken from p.7 21 5.9.5

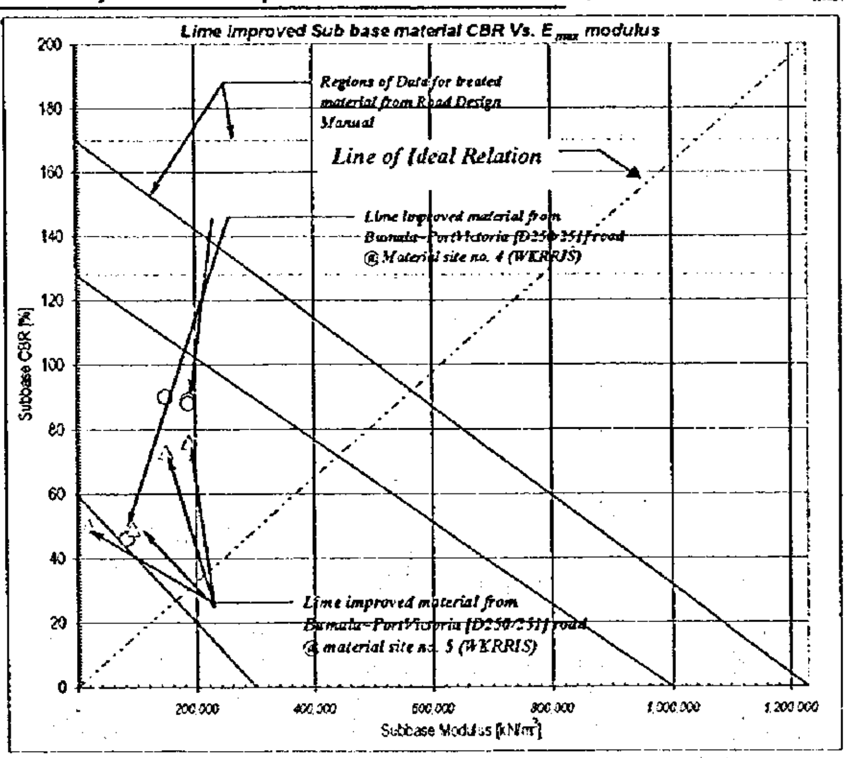


Fig. 7.1.2(b): RDM & WKRRI Study area LIME Improved material for Sub base, CBR Vs. moduli, $(E_{50})_T$ plo

Ref	Proposed Sub-base Material (treatment)	CBR [%]	Sub-base $(E_{50})_T$ [kN/m2]
RDM	SB1	80	300,000
RDM	SB2	120	840,000
RDM	SB3	170	1,220,000
RDM	base	230	1,696,000
RDM	base	380	2,340,000
RDM	base	500	4,580,000
MS4 (7 day)	2% Lime	58	20,192
MS4 (7 day)	Con Aid+ 2% Lime	48	20,120
MS4 (7 day)	3% Lime	68	20,120
MS4 (7 day)	5% Lime	90	30,389
MS5 (7 day)	2% Lime	70	34,310
MS5 (7 day)	Con Aid+ 2% Lime	73	23,204
MS5 (7 day)	3% Lime	50	8,182
MS5 (7 day)	5% Lime	48	27,070

MS denotes Material Site for West Kenya Rural Roads Improvement Study area
RDM = Kenya Road Design Manual
Data taken from p.7.21 & 7.5

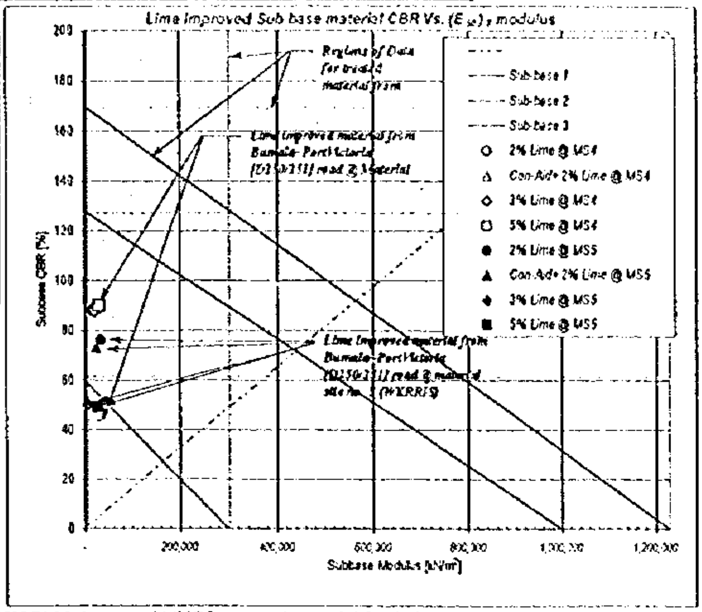
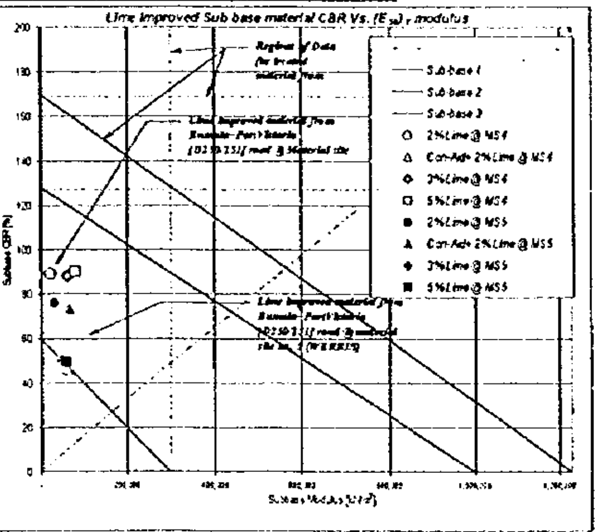


Fig. 7.1.2(c): RDM & WKRRI 14 day cured LIME Improved material for Sub base, CBR Vs. moduli, $(E_{50})_T$ plot

Ref	Proposed Sub-base Material (treatment)	CBR [%]	Sub-base $(E_{50})_T$ [kN/m2]
RDM	SB1	80	300,000
RDM	SB2	130	999,000
RDM	SB3	170	1,220,000
RDM	base	230	1,696,000
RDM	base	380	2,340,000
RDM	base	500	4,580,000
MS4 (14 days)	2% Lime	[illegible]	[illegible]
MS4 (14 days)	Con Aid+ 2% Lime	50	62,362
MS4 (14 days)	3% Lime	88	62,362
MS4 (14 days)	5% Lime	108	80,264
MS5 (14 days)	2% Lime	73	32,045
MS5 (14 days)	Con Aid+ 2% Lime	75	58,952
MS5 (14 days)	3% Lime	48	[illegible]
MS5 (14 days)	5% Lime	45	61,488

MS denotes Material Site for West Kenya Rural Roads Improvement Study area
RDM = Kenya Road Design Manual
Data taken from p.7.21 & 7.5



7.2 Proposals For New Approaches

This study has proposed various methods of analysing experimental data for purposes of determining more precise design parameters. Plots such as those shown in Figs. 7.1.1 and 7.1.2 whereby more than one parameter is adopted to make an engineering decision is considered an imperative approach. The application of counter check methods by adopting generalised state equations or relations for analysis of experimental data is highly emphasised. Further R & D that would enhance new approaches to facilitate more precise design specifications is an issue of paramount importance in Geotechnical Engineering in Kenya.

8. Conclusions

This study has shown that the behaviour of a geomaterial can be complex in the sense that it does not necessarily respond consistently to various mechanical tests based on the conventional approach. It was observed for example, that materials sampled from different material sites varied in their response to varying modes of treatments. It would therefore be uneconomical to generalise one mode of treatment for all materials.

The importance of adopting a comprehensive analytical approach in fostering R & D for purposes of establishing specifications that are relevant and suitable for Kenyan or tropical conditions has been clearly demonstrated.