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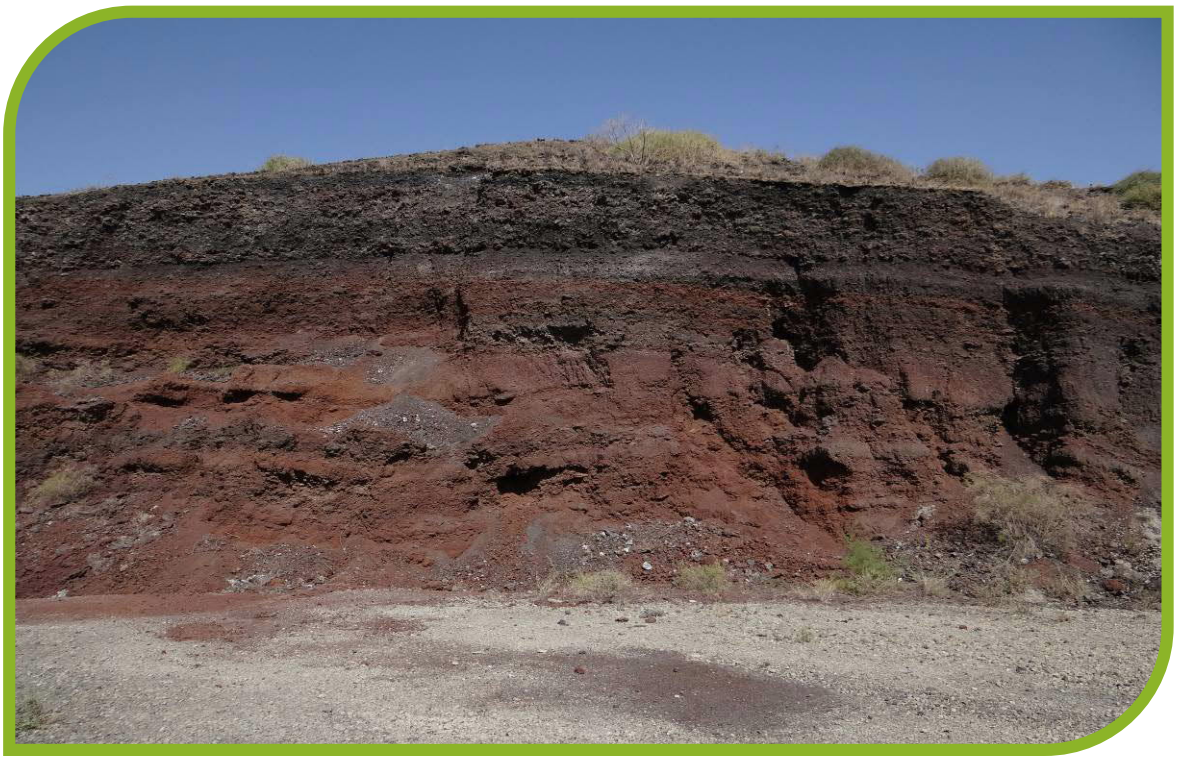
Investigation of the Use of Cinder Gravels in Pavement Layers for Low-Volume Roads

Progress Report No 5



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Abstract

This Progress Report summarises progress made on the Project during March - June 2017. During this period the cinder gravel testing has been completed and the results have been reviewed, both in terms of engineering implications and potential future source areas. All field engineering geological field data has been reviewed and summarised, and the engineering geological descriptions of material strength have been compared with the lab test data. Geographical areas where cinder gravels appear to be, on the whole, stronger than others have been identified, and the Debre Zeit (Bishoftu) and Butajira areas were selected for ground truthing. Visits were made to cinder cones in these areas and additional samples were collected for AIV testing. These test results were received at the end of June and have been reviewed as part of this Progress Report. Generally, the materials tested during the ground truthing were found to be suitable either as base or sub-base (though there are some exceptions) and the engineering geological descriptions were generally supported by the AIV results.

Key words

Low Volume Roads, Guideline, Pavement Layers, Scoria, Cinder gravels, Ethiopia

Acronyms, Units and Currencies

AADT	Annual Average Daily Traffic
AfCAP	Africa Community Access Partnership
AIV	Aggregate Impact Value
CBR	California Bearing Ration
EF	Equivalence Factor
ERA	Ethiopian Roads Authority
EMA	Ethiopian Mapping Agency
LAV	Los Angeles Abrasion Value
LL	Liquid Limit
LVR	Low Volume Roads
LVSR	Low Volume Sealed Roads
MAIV	Modified Aggregate Impact Value
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PI	Plasticity Index
ReCAP	Research for Community Access Partnership
RRC	Road Research Centre
TFV	Ten percent Fines Value
TRL	Transport Research Laboratory
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)
WA	Water Absorption
%	Percentage
g/cc	Grams/cubic centimetre
kN	Kilo newtons
Mm	Millimetres
µm	Micrometres

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1 Introduction

This Progress Report No 5 covers the period March-June 2017. The structure of the project is described in the Inception Report and this Progress Report should be read in conjunction with it.

2 Summary of key activities undertaken during this Period

The following activities were planned for the period:

1) Ground truthing. During this period, the Team Leader visited Ethiopia in order to carry out the 'ground truthing' studies. This was planned to take place at the end of April on the basis that the RRC would have completed laboratory testing relevant to the exercise. The laboratory testing of priority samples at the RRC laboratory was only completed at the end of May 2017. The ground truthing was done from 18th to 25th June 2017.
   Prior to the ground truthing exercise, compilation of the engineering geological fieldwork data into a tabulated summary and comparison of visual strength with source location parameters, including cone geometry, underling geology and geographical region were carried out. In addition, comparison of visual strength with laboratory test data to identify areas of strong source material clusters for was carried out.
   During the ground truthing, visits were made to existing and potential source areas in Debre Zeit , Bishoftu, Injibara and Bahir Dar to collect additional samples for AIV testing.
2) Preparation of samples for XRD and XRF testing. This required that the RRC obtain export permits from the Ministry of Mines in Ethiopia, for the samples. In addition, the test samples had to be prepared in suitable sizes ready for transport. Export permits have not yet been obtained but ERA have been assured that the permits will be issued within a short time once the flight details of the travelling RRC counterparts have been supplied.
3) Analysis of available laboratory results. These were done in preparation for the ground truthing. Further analysis of the results for inclusion in the guideline is being undertaken and more will be done together with the RRC counterparts.
4) Drafting of the Guideline. It was planned that the table of contents for the Guideline will be agreed with the counterparts. This was done.

These activities are described in Sections 3 to 6 below.

3 Ground truthing

3.1 Analysis of laboratory test results to prepare for ground truthing

During this Period, a programme was devised to expedite and bring the laboratory testing at the RRC to an end. This was required due to the slow progress of testing at the laboratory and the need to finalise the results in advance of the 'ground truthing' (Section 3.4 below). Accordingly, the curtailment of the testing reduced the scope to AIV tests, Specific Gravity, and Water Absorption on single samples from the remaining sites.

Test results were tabulated for each sample location. CBR and dry AIV test values were used to assign sample suitability for use as base course and sub base. Generally, CBRs above 60% were considered suitable for base course and CBRs above 30 were considered suitable for sub-base. AIV less than 40% was considered suitable for base whereas AIV less than 50% was considered suitable for sub-base. The cut-off AIV values will be revised on the basis of further test results that will soon be received from the laboratory based on the modified tests.

3.2 Compilation of engineering geological field work data

A tabulated and photographic record has been developed of all areas visited during the main phase of fieldwork in 2016. This includes all cinder cones and other exposures where samples were taken for laboratory testing, as well as those locations visited from which samples were not taken. The exposed materials in the cinder cones are typically formed in thin beds orientated parallel to the sloping surface of the cone. These beds are usually very-well defined, and are normally composed of internally-consistent material. However, there can be a significant difference between the size, shape, vesicularity, density and strength of the material in adjacent beds, so that any given cone can contain a wide range of stronger and weaker materials. During the main phase of fieldwork, it was usual to describe a number of beds of varying strength, with between 1 and 3 samples taken for testing.

Summary tables were prepared that provided details of the location and setting of each cinder cone, the underlying geology, the findings of the aerial photograph interpretation (Progress Report No 3), cone geometry and the visual strength of the beds from which samples had been taken. A composite description of overall strength was provided for each site based on the range of materials observed. A photographic record was also developed of each location visited.

3.3 Comparison of visual strength with laboratory test data

The AIV and CBR test results were compared with the composite visual strength descriptions derived from the field inspections. Table 3-1 shows this comparison and indicates in the left hand column in green where there is consistency in the field descriptions with either of the lab test results for AIV or CBR. Locations where the site's visual descriptions indicated stronger materials than those derived in the laboratory are shown in red in the left hand column. As can be seen there is general correspondence between the field identification of stronger materials and the lab test results (either AIV or CBR) for base course suitability. There are three locations where the field descriptions identified strong materials that were not corroborated by the laboratory test data (either MAIV or CBR).

Table 3-1: Comparison between field material strength descriptions and lab test results

LOCATION	VISUAL DESCRIPTION ON SITE W = Weak; S = Strong; V = Very; M = Moderately	LABORATORY TESTS	
		SUITABLE FOR BASE (AIV)	SUITABLE FOR BASE COURSE (CBR)
1	MS-S	37	Base
2	MW-MS	44	Sub-base
3	MW-S	37	CBR 100 Base
4	W-S	38	Base
5	W-MS	39	CBR 120 Base
6	W-MS	38	CBR 62 Sub-base but can be Base since it is Cat 2
7	MS-S	40	CBR 58 Sub-base
8	W	48	CBR 48 Sub-base
9	W	44	Sub-base
10	W	62	Not suitable for use
11	MW-S	54	CBR 54 Sub-base Marginal
12	MS-S	25	Base

13	MW-MS		CBR 60 Sub-base but can be Base Cat 2
14	W	17	CBR 41 Sub-base
15	S-VS	40	Base
16	W	50	WA 17 Not suitable for use
17	S-VS	37	CBR 95 Base
18	W	32	Base
19	S-VS	43	CBR 148 Base
20	MS-S	71	WA 33 Not suitable
21	MS-VS	8.7[1]	CBR 57 Base
22	MW-MS	37	WA 14 Sub-base/Base
23	VW-MS	23	CBR 67 Base
24	S	29	CBR 90 Base
25	MS	25	CBR 90 Base
26	MW-MS	35	WA17.7 Sub-base
27	VW-W	47	CBR 44 Sub-base
28	S-VS	34	Base
29	S-VS	34	Marginal Base
30	MW-S	40	Base

1. Retest has been requested

Green = Site description shows moderate strength to strong materials that are consistent with suitability for base course, as defined by either AIV or CBR

Orange = Site description shows moderate material strength, not reflected in lab test base course suitability results

Red = Site description shows strong material, not reflected in lab test base course suitability results

Those locations where there was coincidence between the field descriptions and the laboratory test results were examined in terms of their geographical distribution as a basis for devising the programme of ground truthing (Section 6). There are apparent clusters of locations that contain better than average material in the vicinity of Debre Zeit and Injibara. It is likely that this clustering is due to the geo-chemical composition of the magma in each case and the manner in which it progressed from the magma to the effusive air-borne state during the formation of each cinder cone. These two areas formed the basis for the ground truthing (Section 6).

3.4 Field exercise of ground truthing

Google Earth imagery was used to identify locations in the Debre Zeit and Injibara areas where field investigations and material testing would be undertaken as part of the ground truthing exercise. In the Debre Zeit area there are several cones, excavations and exposures that were not visited during the main 2016 phase of the fieldwork. In total six locations were identified in the Debre Zeit area from the imagery and an additional site was located during the fieldwork itself. Table 3-2 summarises the field descriptions of material strength at the ground truthing locations in the Debre Zeit area and allows comparison with the AIV test data in each case.

Table 3-2: Field descriptions and laboratory tests from Debre Zeit ground truthing sites

Ground truthing location	Field description of strength	Average AIV%
GT1	Very weak to moderately weak	56
GT2	Moderately weak to very strong (maar rim)	11

GT3 black GT3 red	Moderately weak to very strong Very weak to weak	54 45
GT4	Strong to very strong	25
GT5	Moderately weak to strong	44
GT6A	Moderately strong to very strong	42
GT6B	Very weak to strong (highly variable)	28

Generally, the field descriptions indicate material varying between moderately weak to very strong. This supports the interpretation made following the main phase of fieldwork and testing (Section 3). There is good correspondence between the visual strength and the test results, and the only anomaly is GT3 red where the visual strength of the material was very weak to weak and the AIV was 45%.

As can be seen from Table 3-1, according to the average AIV values, the materials are generally representative of stronger rather than weaker materials. Based on the AIV test results, samples GT2, GT4, and GT6B could probably be suitable for use as base course and others could probably qualify for sub-base.

In the Butajira area, there are several volcanic landforms, including large volcanoes, maars, tuff rings and cinder cones. Several sites were identified on Google Earth and these were visited during the ground truthing exercise. In addition, one other main site in the Bahir Dar area that had not been sampled during the 2016 phase of fieldwork was also identified. This location (GT15 in Table 3-3) was described as strong to very strong material, and appears to be a good source of cinder gravel in an area that is otherwise somewhat deplete. One location (U11) in the Bahir Dar area that was visited in 2016 but from which no samples were taken at the time due to prevention from local people, was sampled during the ground truthing exercise. This was described as very weak to weak material (Table 3-3) consistent with several other samples from the Bahir Dar area.

Table 3-3: Field descriptions and laboratory tests from Injibara/Bahir Dar ground truthing sites

Ground thruthing location	Field description of strength	Average AIV%
GT7	Strong to very strong gravel on maar slope surface – indicative of strong gravels at depth (?) below 1-3m of residual soil. NB sample taken of dozed material only (materials dozed out of way to provide space for crusher plant using imported igneous material), but sample assumed to be derive from original site material	45
GT8	Residual soil only, any gravels too deep to be seen/sampled	No sample taken
GT9	Not visited	No sample taken
GT10	Deep residual soils formed on maar slopes – no gravel exposure, though occasional weathered gravel on slope surface – moderately weak to strong – indicative of strong gravels at depth (?)	No sample taken
GT11	Weak to very weak. Borrow area located in unconfirmed linear volcanic landform, either a lava flow or part of an ancient maar	46 (red/brown) 36 (dark grey)

GT12	Deep residual soils exposed on maar side slopes. No gravel identified	No sample taken
GT13	Non-vesiculated basalt gravel, probably strong (lower slopes of maar rim) – indicative of strong gravel at depth	No sample taken
GT14	Not visited	No sample taken
GT15	Strong to very strong (new location in Bahir Dar area)	25
U11 black U11 red	Weak to moderately strong Very weak to weak	37 50

As can be seen from Table 3-3 a number of the locations identified from Google Earth contained gravels that appeared to be unvesiculated and strong on the surface, but there was insufficient exposure to collect samples. These locations are on the rims of maars and not cinder cones per se. The cinder cones in the Butajira are often located at some distance from the road network and, from Google Earth imagery, do not appear to have been explored as yet as material sources. Consequently, these areas could not be sampled during the ground truthing exercise, but they might represent suitable sources of material. Of the two sampled areas in the Injibara area where samples were taken, one (GT7) was on the rim of a maar and the other (GT11) was in a volcanic landform yet to be defined. The material at GT7 was described in the field as being strong in engineering geological terms. Upon testing, this material was found to have an AIV of 45%. The material at GT11 was described in the field as being weak in engineering geological terms. Upon testing, this material was found to have an AIV of 36-46%. The new location (GT15) close to Bahir Dar that was considered in the field to comprise strong materials, yielded an average AIV of 31%, whereas the previously unsampled location (U11), that was considered in the field to be composed of weak materials, yielded average AIVs of 37-50%. Based on the AIV test results, samples GT15 and U11 Black could probably be suitable for use as base course and others could probably qualify for sub-base.

4 Preparation of samples for XRD and XRF testing

The target at the onset of the reporting period was to obtain the export permit and bag on the samples ready for transport. ERA submitted written requests to the Ministry of Mines, and was informed that the permits will be issued when the flight details of the accompanying staff are confirmed. The process, they were assured, is simple and quick once the details are provided. The flight details of the accompany counterparts will be obtained in the next reporting period.

The counterparts will travel with samples to be tested in the UK in the next reporting period. ERA confirmed the names of the counterparts in June 2017 and visa letters for their application were sent from TRL to the counterparts at the end of June 2017.

The test samples (36 samples each weighing 500 g) have been appropriately prepared and are ready for the trip planned in the next reporting period. The trip is planned for 5th – 20th August 2017 – subject to the dates when the counterparts will obtain their UK visas.

5 Analysis of available laboratory results

This was divided into two groups - results necessary for use in ground truthing, and results necessary for the overall drafting of the Guideline.

The first lot comprising mainly maximum dry density, CBR, AIV, and Specific Gravity were done in preparation for the ground truthing.

Further analysis of the results for inclusion in the Guideline is being undertaken in the current progress period. The results (both field and laboratory test results) are being

analysed holistically to provide a better understanding of the cinder gravels. More of the analysis will be done together with the RRC counterparts for purposes of capacity building. The analysis is being done in comparison to the Ethiopia Low Volume Roads Manual 2017 Part B. Summarised results from two typical sample locations (Location Y and Z) are shown in Table 5-1 and comparison with the grading envelope from the Ethiopia Low Volume Roads Manual 2017 Part B is shown Figure 5-1.

Table 5-1: Typical results of materials tested

Material	4-days soaked CBR at 56 blows	MDD (g/cc)	OMC (%)	Plasticity Index
Location Y				
Category 1 (Non-plastic Cinder)	52	1.76	18.4	Non-plastic
Category 4 plastic blending material	30	1.46	15.5	20
Crushed Stone	79	2.16	4.0	Non-plastic
Blended material (50% Category 1+20% Category 4+30% Crushed Stone)	55	1.58	22.5	Non-plastic
Location Z				
Category 1 (Non-plastic Cinder)	47	1.80	15.8	Non-plastic
Category 4 plastic blending material	18	1.31	31.6	29
Blended material (75% Category 1+25% Category 4)	24	1.55	21.0	23

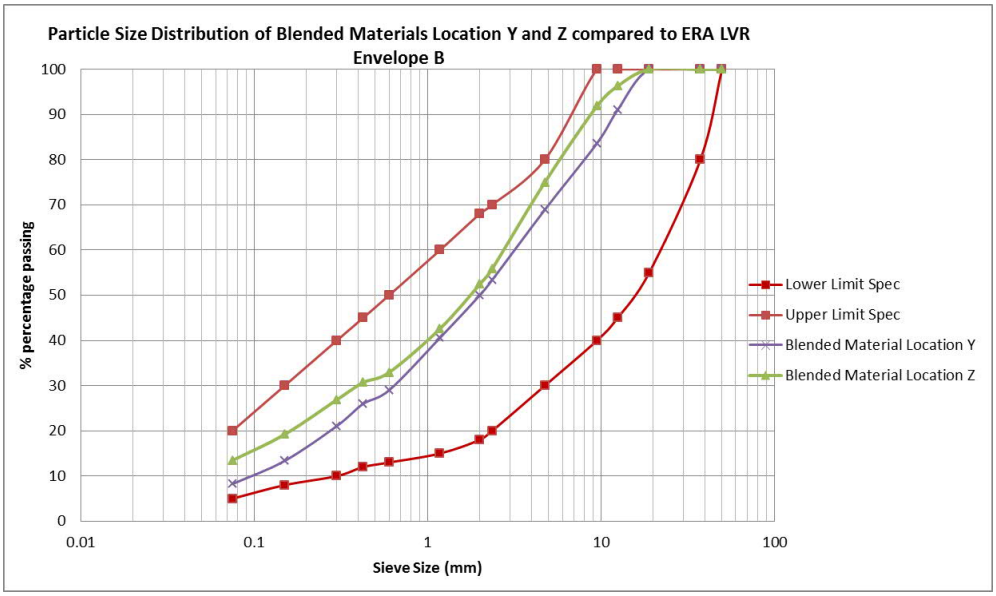

Figure 5-1: Comparison of blended material with LVR grading envelope

6 Drafting of the Guideline

It was planned that the table of contents for the Guideline will be agreed with the counterparts. This was done but may be subject to change during the drafting. The major chapters agreed are as follows:

1. Introduction
2. Previous work on the use of cinder gravels in low volume road construction and maintenance
3. Cinder gravel occurrence in Ethiopia
4. Broad classification of pyroclastic rocks and deposits
5. Desk study, field observations and sampling strategy
6. Engineering geological findings of desk study and field observations
7. Engineering properties of cinder gravels
8. Cinders for subgrade replacement and capping
9. Cinders for sub-base layer
10. Cinders for base layer
11. Cinders as surfacing aggregate
12. Cinders as gravel wearing course
13. Sustainable use of cinders
14. References
15. Appendices

7 Plans for the next reporting period

During the next progress-reporting period, 1st July 2017 to 30th August 2017, the planned activities are:

1) XRD and XRF testing. It is proposed that this will be done at the University of St Andrews in the UK. The RRC counterparts will travel to the UK to participate in this.
2) Analysis of the laboratory test results. The laboratory testing in Ethiopia has now been completed. The results will be analysed together with the counterparts when they travel to TRL in UK.
3) Drafting of the guideline and circulation for review. Following the analysis of the laboratory test results, some sections of the Guideline will be assigned to the RRC counterparts to write. This will be reviewed by TRL experts as part of capacity building. This will prepare the counterparts for participation in writing the

academic paper at the end of the project. It is important to note that some of the drafting has already begun.

Due to delays experienced in laboratory testing, it will not be possible to conduct the stakeholder workshop in August 2017. It is now proposed that the Stakeholder workshop be held during the week 4-8 September 2017. This date is tentative, pending confirmation of availability of ERA key officials.

Firm options for all the TRL experts to be present at the workshop are currently being explored.

8 Issues to take forward to the next Period

XRD and XRF testing is still pending. These results will need to be assessed and included in the overall interpretation when ready.

PROPOSED REVISED ACTIVITY AND MILESTONE SCHEDULE TRL UK LTD

ETH2058A: Investigation of the Use of Cinder Gravels in Pavement Layers of Low Volume Roads

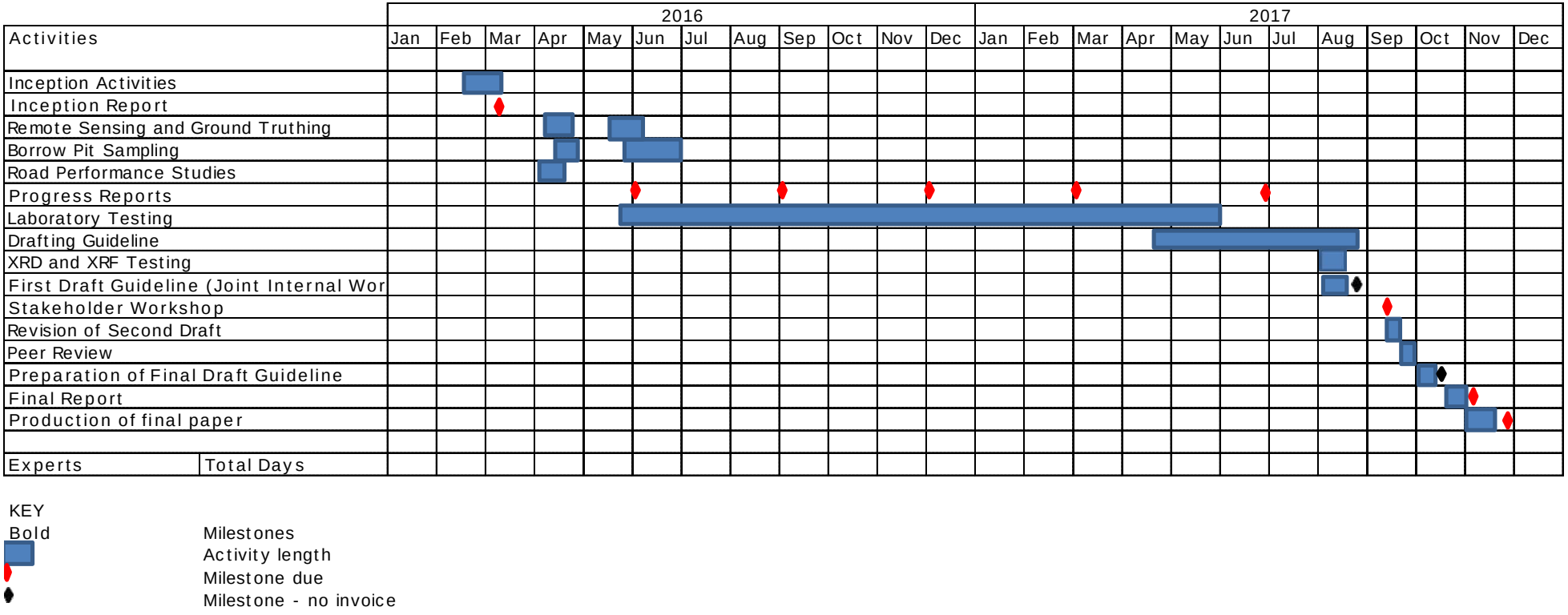

Figure 8-1: Project Schedule