# SEACAP 24/001

# A CASE STUDY OF THE PREMATURE FAILURE OF A TRIAL ROAD IN DAK LAK PROVINCE, VIETNAM

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## INTRODUCTION

In Vietnam the rural communities and their Government face many challenges in achieving national development and reducing rural poverty. Improving rural access and developing rural road networks are national priorities. The provision of sustainable, value-for-money, all season, all weather access for rural communities promotes growth and gives people opportunity to access economic, health and social opportunity. Rural roads are of vital importance to rural communities for their economic and social wellbeing and reduction of poverty. As take-up of economic opportunity arises from access provision, a more diverse vehicular fleet will emerge. Table 1 shows the variation in rural traffic patterns from typical provinces in Vietnam. The essential challenge for engineers and road managers is how to provide and maintain this rural access for the types of traffic in use, on a sustainable basis with the limited available resources.

In response to the increasing recognition that gravel surfacing was not a universal solution for rural roads in Vietnam, the Ministry of Transport (MoT) in 2002 requested studies of alternative surfaces for rural roads as part of the World Bank-funded Rural Transport Programme 2 (RTP2). These studies became known as the Rural Road Surfacing Research (RRSR) initiative, through which the Rural Road Surfacing Trials (RRST I and RRST II) were carried out. This research programme and its extensions were incorporated into the DfID-funded South East Asia Community Access Programme (SEACAP), which is a growth targeted transport initiative facilitating the improvement of sustainable access to rural communities, centred on Vietnam, Cambodia and Laos PDR.

Three trial roads were constructed in Dak Lak province under the RRST-II programme (2005-2006), which followed on from the earlier RRST-I (2002-2005) programme Supervision was undertaken by local consultants with International Consultants Intech-TRL had an overall Quality Assurance and strategic guidance role.

The trial roads in Dak Lak were completed by July 2006 and shortly after that in December 2006 the Buon Ho road was reported to have suffered rapid deterioration on some sections. The Dak Lak trial roads are located within the Central Highlands region of Vietnam, Figure 1

**Table 1: Typical Vietnam Rural Road Traffic Data**

| | | 24 hour Traffic | | | |
|---|---|---|---|---|---|
| | **Province: Road** | **Motor vehicle/day** | **Motorcycle/day** | **Cycle/day** | **ADT** |
| Mekong Delta | Dong Thap: Tan Thuan Tay | 0 | 1718 | 1085 | 226 |
| | Tien Giang: My Phuoc Tay | 2 | 1110 | 646 | 143 |
| Central Coastal | Da Nang: Binh Ky | 16 | 443 | 113 | 50 |
| | Hue: Thong Nhat | 24 | 694 | 706 | 105 |
| Central Highlands | Gia Lai: Ia Pnol | 101 | 134 | 1064 | 67 |
| | Dak Lak: Cu Ne | 176 | 1150 | 106 | 120 |
| | Dak Lak: Buon Ho | 277 | 469 | 56 | 50 |
| Red River Delta | Hung Yen: Nhat Quang | 130 | 176 | 229 | 29 |
| | Hung Yen: Tan Hung | 272 | 140 | 154 | 22 |
| | Ninh Binh: Yen Trach | 152 | 1760 | 2029 | 278 |
| | Ninh Binh: Thu Trung | 168 | 2069 | 2123 | 313 |
| Northern Highlands | Tuyen Quang: Lang Quan | 101 | 907 | 1025 | 142 |
| | Tuyen Quang: Thang Quan | 20 | 266 | 726 | 63 |
| | Tuyen Quang: Y la | 148 | 1249 | 1304 | 190 |
| | Quang Binh: Cam Lien | 31 | 540 | 305 | 69 |
| | Ha Tinh: Thach Minh | 67 | 572 | 776 | 96 |

Note: ADT (average daily traffic) calculated from factoring of all traffic types

**Figure 1 Trials Location**

The Buon Ho deterioration was confirmed during a condition monitoring survey in March 2007 and recommendations were made as a research programme to investigate the causes, which was undertaken by TRL-OtB during late 2007 and early 2008.

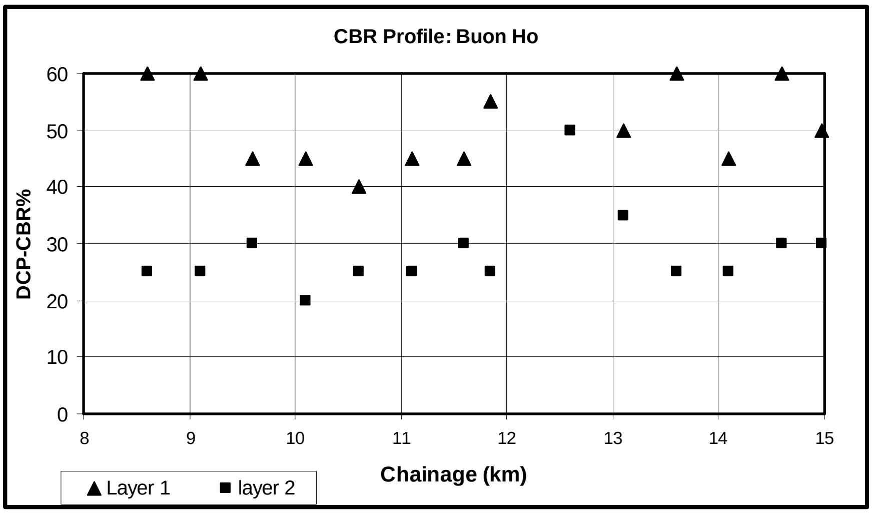
## THE TECHNICAL BACKGROUND

The Buon Ho pavement trial options evolved from consultation between the PDoT/PPMU[1] and the Intech-TRL team and were the result of balancing the following general issues;

- The need to comply with World Bank Rural Transport Programme 3 (RT3) guidelines on road standard (in this case Commune Class A)
- Research objectives of the RRST-II programme
- Available materials
- PDoT design preferences
- Budget constraints

Prior to the trials programme the Buon Ho road was primarily of unsealed gravel construction with some sections of Penetration Macadam. The existing surface was in poor condition and composed of sub-standard quality gravely silty clay, Figure 2.

**Figure 2 In Situ Strength of Existing Pre-Trial Road**




Buon Ho trial road was designed with four different pavement options as described in Table 2. The designs were based on existing Commune Class A guidelines and taking into account the following key points:

- A minimum sub-grade in situ CBR of 15%
- Established local Penetration Macadam design for control sections
- Estimation of likely traffic based on available traffic counts (approximately equivalent to 75,000-100 000 ESA for a 10 year design life)
- 6T maximum axle load.

[1] Provincial Department of Transport = PDoT, Provincial Project Management Unit = PPMU

**Table 2 Buon Ho Trial Pavement Designs**

| Section | Surface/Base | Sub-Base | Design Reference | Chainage (km) |
|---|---|---|---|---|
| 1. BH1 | 60mm of Penetration Macadam | 100mm of water-bound macadam (WBM) | CH8 | 3.700 – 4.166 |
| 2. BH2 | 60mm of Penetration Macadam | 100mm of water-bound macadam (WBM) | CH8 | 5.100 – 5.316 |
| 3. BH3 | Double stone (hot bitumen) chip seal on 100mm dry-bound macadam (DBM) | 100mm DBM | CH5 | 8.600 – 9.100 |
| 4. BH4 | Sand and stone chip emulsion seals on 100mm dry-bound stone macadam (DBM) | 100mmDBM | CH4 | 9.100 – 10.100 |
| 5.BH5 | Double stone chip emulsion seal on 100mm dry-bound stone macadam (DBM) | 200mm of natural gravel placed and compacted in two layers | CH3 | 10.100 – 12.600 |
| 6. BH6 | Double stone chip emulsion seal on 100mm dry-bound stone macadam (DBM) | 200mm of natural gravel placed and compacted in two layers | CH3 | 12.600 – 14.980 |

The RRST-II Buon Ho trial section was construction during February to May 2006 in three contract packages each with a different local contractor, as follows:

- Package I: Sections BH1; BH2; BH3 and BH4
- Package II Section BH5
- Package III Section BH6

An as-built Quality Assurance survey was combined with an assessment of available test data to give an overall Quality Assessment as summarised in Table 3.

**Table 3 As-Built Quality Assessment**

| Section | As Built Survey | |
|---|---|---|
| | Visual Assessment | Materials |
| 1. BH1 | B | B |
| 2. BH2 | B | B |
| 3. BH3 | A | B |
| 4. BH4 | B | C |
| 5.BH5 | B | B |
| 6. BH6 | A | B |

Where A: Satisfactory
B: Some unsatisfactory issues or missing data
C: Unsatisfactory

In addition, the following specific points were made;

1. Crossfalls were not as specified in all sections except section 6
2. The sand seal was not satisfactory (CH4)
3. There was a lack of some quality control DCP test results
4. Some CBR laboratory test results from as-delivered material were low
5. Some particle size distributions for DBM and WBM aggregate were poor
6. There was insufficient site and laboratory data from section 4

During construction the poor quality of the gravel sub-base for Sections BH5 and BH 6 was noted and a change of materials was recommended. It should also be noted that test results for as-delivered construction materials were not submitted to Intech-TRL until after completion of construction.

Also during the construction period, the PDoT indicated that they proposed to upgrade this road to provincial level and observations by Intech-TRL of traffic using completed sections indicated that there was already a significant risk of heavy traffic using the road. Recommendations on this were made to the PDoT in regard to the unsuitability of using a Commune A pavement design for provincial level traffic and the consequent desirability of restricting heavy vehicles using the Buon Ho road.

In December 2006, approximately 6 months after completion of the road, the Dak Lak PDoT reported that sections were suffering from severe rutting of the pavement, cracking of the surface seals and erosion of some base aggregate. The PDoT also indicated that according to local reports, the road was being subjected to significant heavy vehicle traffic and that it was not possible to restrict this with the use of width barriers.

An Intech-TRL team visited the Buon Ho trials and held discussions with the PDo/PPMU. The following were the principal points raised in the subsequent report.

1. After completion of construction, the truck traffic on the Buon Ho road has increased substantially and very quickly as trucks preferred to go along Buon Ho – EaDrong (Trial Road) from Khanh Hoa province to Buon Ho town (Krong Buk district). Thus not only do they avoid going through Buon Ma Thuot city, thereby saving 70km, they also avoid the toll station near Buon Ho town.
2. Some short sections of trial road are damaged because of the overloaded vehicles. Provinces in the Central Highland are unwilling or unable to use barriers to control the heavy vehicles. There are load limit signs along the road but drivers do not comply with these restrictions.
3. According to local residents, the heavy vehicle traffic continues during the night up to around 02:00hrs.

The following damaged sections were noted:

- Km 8 +950 (BH3) badly damaged length about 80m
- Km 9 + 400 (BH4) badly damaged length about 20m.
- Km 10 + 200 (BH5)badly damaged length about 30m

It is understood that uncontrolled heavy vehicle traffic continued to use the Buon Ho trial road and that rapid deterioration of the pavement continued until, by late 2007, the condition had deteriorated to such an extent in some places that most of this traffic opted not to use the road.

# THE INVESTIGATION

At the request of the MoT a study into the Buon Ho pavement failure was funded by SEACAP and imitated in November 2007. The main investigation comprised the following:

1) Excavation of inspection pits in the trial pavements
2) In situ testing (DCP)
3) Sampling of as-constructed materials
4) Visual inspection of whole trial road lengths
5) Collection of relevant traffic data
6) An axle load survey the Buon Ho and adjacent provincial roads.

A total of 10 inspection pits were excavated and sampled on the Buon Ho road on a representative sample of differing pavement conditions. In situ DCP testing was undertaken on pavement layers within the inspection pits where appropriate. Samples recovered from the inspection pits were assigned for testing at a local laboratory and at a selected geotechnical laboratory in Hanoi, as follows:

- DBM/WBM base or sub-base) – for grading
- Pen Mac/ DBST for bitumen content
- Gravel sub-grade/sub-base for grading, moisture content, plasticity, compaction and d CBR.

Test results are summarised in Tables 4 and 5.

A visual condition survey was undertaken of the whole of the Buon Ho trial road using an assessment ‘block’ length 25m. Figure 3 presents a typical wheel-track rut depths plot measured as part of the visual survey procedure. Visual descriptions were grouped into 5 general levels of condition as defined below and presented in Figure 4, which also includes test pit locations, pavement design references and contractor boundaries.

The pavement condition groups were:

1. Pavement in **good** condition, with only occasional isolated cracking and occasional minor ruts <20mm
2. Pavement in **fair** condition, with some slight stripping of seals leading to occasional shallow potholes; occasional rutting up to 20mm, occasional interconnected or crocodile cracking
3. Pavement in **moderately poor** condition, with significant crocodile cracking and scattered potholes, rutting may be up to 70-80mm
4. Pavement in **bad** condition, extensive crocodile cracking and potholes with rutting up to 200mm
5. Pavement in **very bad** condition – essentially pavement has lost seal and lost integrity with severe ruts and loosening of base material.

**Figure 3. Rut Depths for Section BH 5**

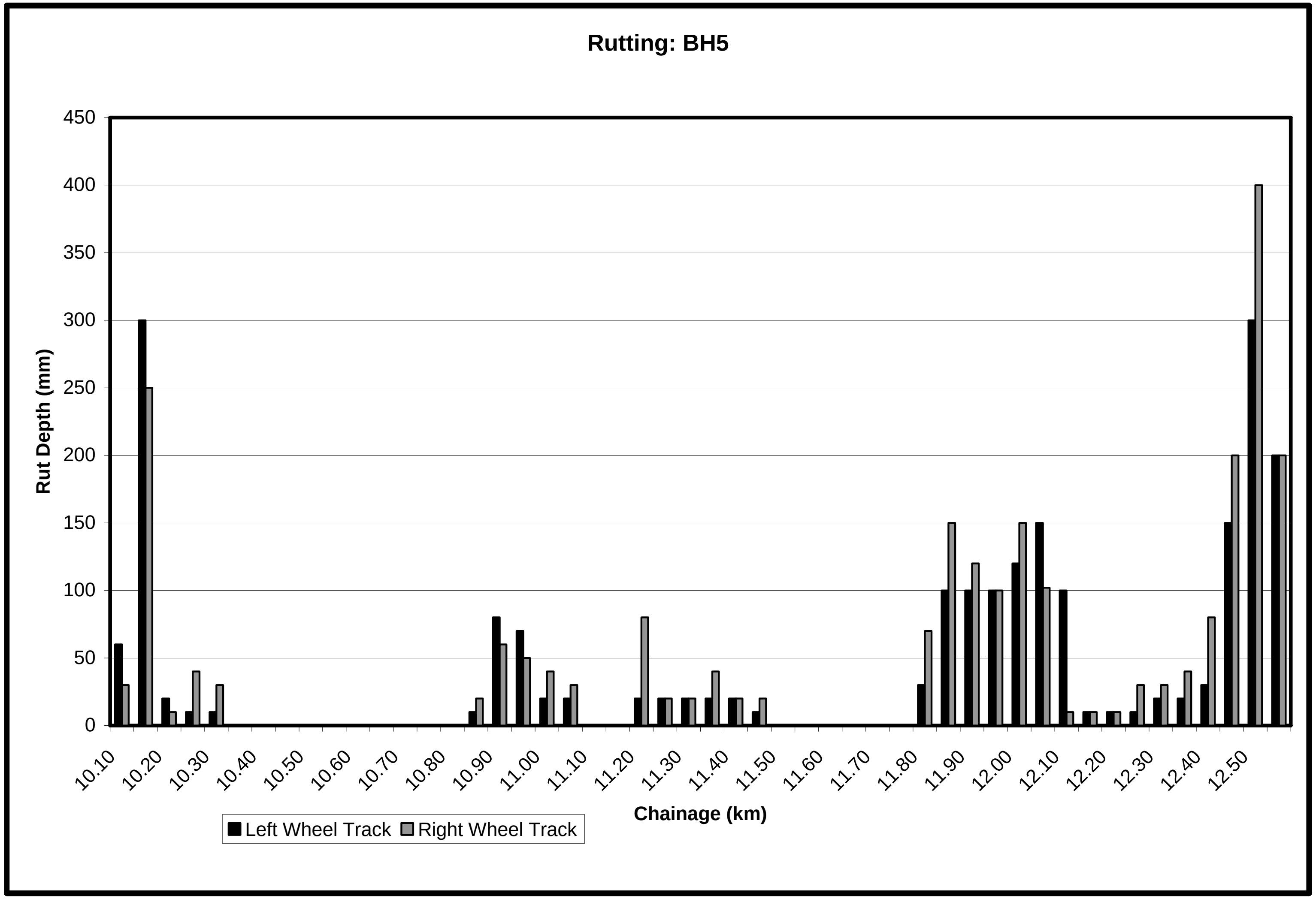


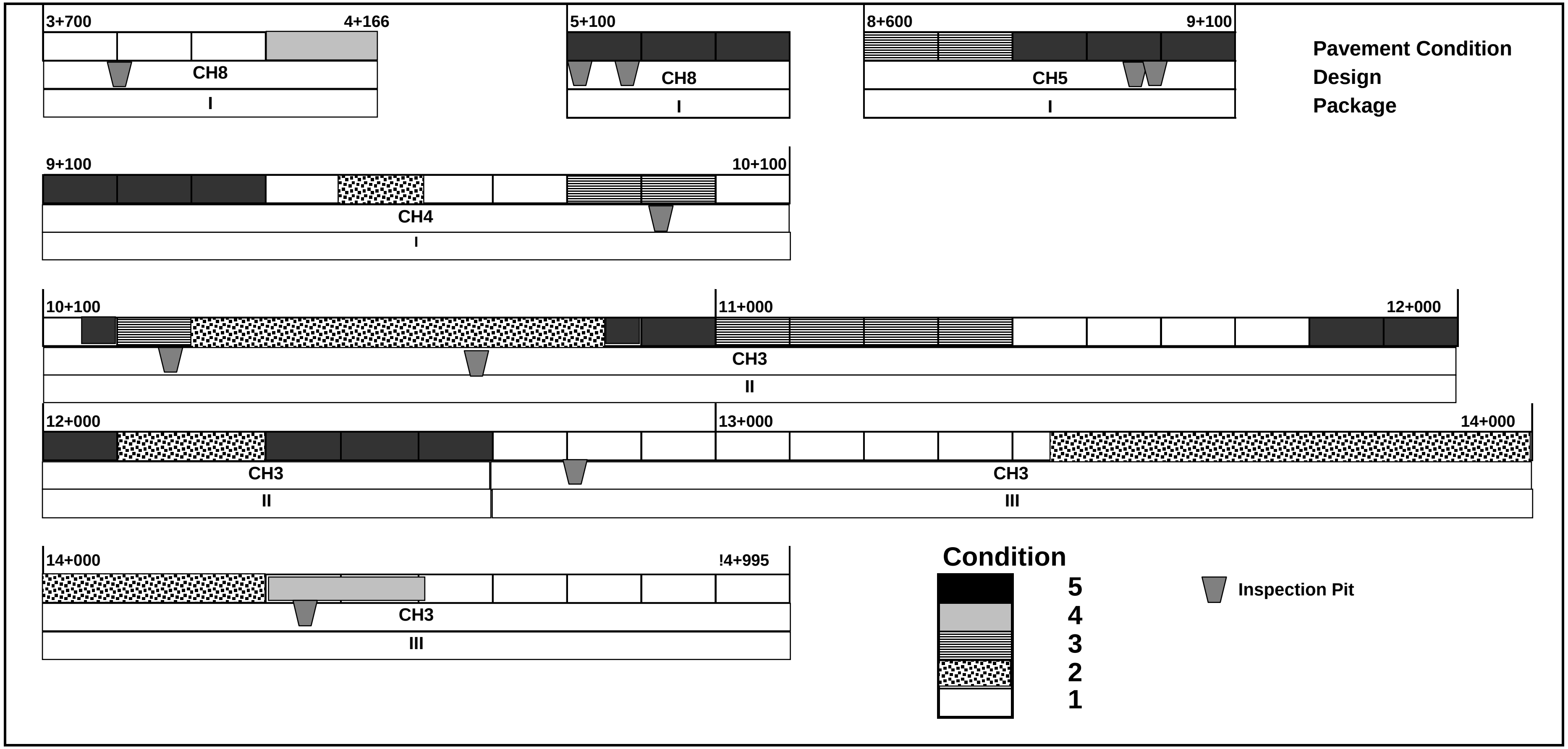
**Table 4 Crushed Stone Aggregate and Bitumen Test Results from SEACAP 24 Inspection Pits**

| Ch. km | Pit No. | Layer | Layer Type | Bitumen kg/m2 | Aggregate | | Comments | Road Condition | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | %>50mm | %<5mm | | At pit | Zone |
| 3+800 | BH1.01 | Sub-base | WBM | | 19 | 2 | | 2 | 1 |
| 5+100 | BH2.01 | Sub-base | WBM | | 11 | 3 | | 3 | 5 |
| 5+190 | BH2.02 | Sub-base | WBM | | 6 | | Clay on aggregate | 4 | 5 |
| 8+960 | BH3.01 | Sub-base | DBM | | 8 | 14 | | 4 | 5 |
| 8+990 | BH3.02 | Sub-base | DBM | | | 21 | | 4 | 5 |
| 9+935 | BH4.01 | Sub-base | DBM | | 31 | 9 | | 4 | 3 |
| | | | | | | | | | |
| 10+275 | BH5.01 | Base | DBM | | 10 | 58 | | 3 | 3 |
| 10+620 | BH5.02 | Base | DBM | | 11 | 7 | | 1 | 2 |
| 12+800 | BH6.01 | Base | DBM | | 17 | 10 | | 1 | 1 |
| 14+435 | BH6.02 | Base | DBM | | 5 | 8 | | 4 | 4 |
| | | | | | | | | | |
| 10+275 | BH5.01 | Surface | DBSTe | 5.53 | 0 | | | 3 | 3 |
| 10+620 | BH5.02 | Surface | DBSTe | 4.31 | 13 | | Fine aggregate segregation | 1 | 2 |
| 12+800 | BH6.01 | Surface | DBSTe | 4.61 | | | | 1 | 1 |
| 14+435 | BH6.02 | Surface | DBSTe | 5.07 | 9 | | | 4 | 4 |
| | | | | | | | | | |
| 3+800 | BH1.01 | Surface+base | PMac | 3.83 | 7 | | | 2 | 1 |
| 5+100 | BH2.01 | Surface+base | PMac | 4.37 | 19 | | | 3 | 5 |
| 5+190 | BH2.02 | Surface+base | PMac | 4.08 | 4 | | Clay on aggregate | 4 | 5 |
| 8+960 | BH3.01 | Surface+base | DBST+DBM | 4.25 | 0 | | Fine aggregate segregation | 4 | 5 |
| 8+990 | BH3.02 | Surface+base | DBST+DBM | 4.76 | 4 | | Fine aggregate segregation | 4 | 5 |
| 9+935 | BH4.01 | Surface+base | SSBSTe +DBM | 3.80 | 14 | | Fine aggregate segregation | 4 | 3 |

**Table 5. Natural Gravel Test Results from SEACAP 24 Inspection Pits**

| Ch. km | Pit No. | Layer | Soil Class | W% | LL% | Ip% | OMC% | MDD g/cm3 | Lab CBR 95% | Lab CBR 98% | W/OMC Ratio | DCP CBR | Road Condition At pit | Road Condition Zone |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3+800 | BH1.01 | Subgrade | SM | 27 | 52 | 17 | 21 | 1.70 | 5 | | 1.29 | 15-30 | 2 | 1 |
| 5+100 | BH2.01 | Subgrade | SM | 22 | 61 | 21 | 19 | 1.80 | 6 | | 1.16 | 34 | 3 | 5 |
| 5+190 | BH2.02 | Subgrade | SM | 28 | 54 | 18 | 19 | 1.70 | 5 | | 1.47 | 11 | 4 | 5 |
| 8+960 | BH3.01 | Subgrade | SM | 22 | 63 | 20 | 17 | 1.73 | 5 | | 1.29 | 12 | 4 | 5 |
| 8+990 | BH3.02 | Subgrade | SM | 17 | 60 | 19 | 24 | 1.69 | 5 | | 0.71 | 24-13 | 4 | 5 |
| 9+935 | BH4.01 | Subgrade | CL | 22 | 31 | 11 | 20 | 1.64 | 5 | | 1.10 | 6-13 | 4 | 3 |
| 10+275 | BH5.01 | Subgrade | MH | 30 | 59 | 16 | 24 | 1.65 | 5 | | 1.25 | 21-14 | 3 | 3 |
| 10+620 | BH5.02 | Subgrade | MH | 21 | 51 | 15 | 23 | 1.71 | 7 | | 0.91 | 25 | 1 | 2 |
| 12+800 | BH6.01 | Subgrade | SM | 19 | 54 | 19 | 22 | 1.63 | 6 | | 0.86 | 36 | 1 | 1 |
| 14+435 | BH6.02 | Subgrade | SM | 21 | 55 | 16 | 20 | 1.66 | 5 | | 1.05 | 25 | 4 | 4 |
| | | | | | | | | | | | | | | |
| 10+275 | BH5.01 | Sub-base | SM | 26 | 60 | 19 | 21 | 1.73 | | 12 | 1.24 | 13 | 2 | 3 |
| 10+620 | BH5.02 | Sub-base | SM | 27 | 63 | 16 | 21 | 1.73 | | 6 | 1.29 | 25 | 1 | 2 |
| 12+800 | BH6.01 | Sub-base | SM | 21 | 57 | 13 | 23 | 1.65 | | 7 | 0.91 | 51 | 1 | 1 |
| 14+435 | BH6.02 | Sub-base | MH | 27 | 69 | 22 | 19 | 1.70 | | 6 | 1.42 | 15 | 4 | 5 |

**Figure 4. Buon Ho Pavement Condition Summary**



# TRAFFIC

The original design traffic count was carried out on the trial road by the PDOT in July 2005 and although the road was in need of repair at that time and therefore the traffic level was probably lower than it would normally have been, the figures indicate an ESA total of between 75,000 and 100,000 for a 10 year design life.

There are five traffic count stations on provincial or national roads in the vicinity of the Buon Ho road and data form these stations for 2005-2007 were used to estimate the traffic that used the trial road after construction both as a short-cut and as a means to avoid tolls. The traffic counts on RN 26 were particularly useful because four counts were made in the period 2006 to 2007, spanning the period when the trial road was first opened to traffic right through to when the road had deteriorated badly and traffic levels decreased as a consequence. The other traffic counts were useful because they provide information concerning the general growth rate of traffic in the area.

An estimate of the traffic that was diverted from the main road to the trial road when it was completed was made by calculating the reduction in traffic observed at the counting station at Krong Pak on the RN26. The increase in traffic again, at a later date when the trial road had deteriorated, also indicates how much traffic used the trial road. In carrying out these calculations, the overall steady growth in traffic was also taken into account. It was also been assumed that the diverted traffic used the trial road for six months and that it started and stopped relatively quickly. Table 6 summarises the calculation.

**Table 6 Calculation of Diverted Traffic (vpd) on to Trial Road**

| Vehicle type | 2006 | | | 2007 | Growth | Diverted traffic | |
|---|---|---|---|---|---|---|---|
| | 1st quarter | 2nd quarter | 3 /4 quarter | | % per annum | Initial | Final |
| Car | 169 | 173 | 154 | 199 | 10 | 34 | 50 |
| Light truck 2 axle | 141 | 136 | 139 | 145 | 2 | N | N |
| Light truck 3 axle | 231 | 245 | 273 | 396 | 41 | 17 | 62 |
| Medium truck | 256 | 312 | 254 | 315 | 13 | 129 | 201 |
| Heavy truck 3-axles | 93 | 94 | 77 | 150 | 35 | 36 | 56 |
| Heavy truck ≥4-axle | 29 | 30 | 20 | 30 | 2 | 14 | 17 |
| Mini bus <20 seats | 150 | 147 | 120 | 151 | 0.5 | 32 | 37 |
| Large bus > 20 seats | 123 | 114 | 126 | 165 | 20 | N | N |
| Total buses | 273 | 261 | 246 | 316 | 9 | 21 | 26 |
| Heavy trucks | 122 | 124 | 97 | 180 | 27 | 50 | 73 |
| Total of trucks | 750 | 817 | 763 | 1036 | 22 | 189 | 325 |

Note N = apparent negative result

The best solution was seen to be to classify all buses together and all trucks together. Growth rates appear to be high, especially for the total of the two classes of heavy truck, but they are similar to the computed rates from the other counting stations. There is considerable variability but if the figures for 'all trucks' and for 'all buses' are computed, the overall growth rates for cars, trucks and buses are remarkably similar at 43%, 39% and 45%.

It was necessary to estimate the normal traffic that used the road in addition to the diverted traffic. The traffic counts on the trial road itself in 2005 and in 2008 used a different classification of traffic and reconciling the two methods was undertaken in terms of total trucks. It is the heavy trucks that contribute by far the most to the damage to the road and it is the number of these for which an estimate was needed. The number of trucks >5T in January 2008 was 51 per day but not all of these are really heavy. The number of heavy trucks is therefore unknown. However, from other traffic count data it was found that the percentage of heavy trucks is about 29% of all trucks and this figure is fairly similar for all count stations. If we,

(a) assume that 29% of all trucks are heavy

(b) assume a growth rate of 27%

(c) work backwards from the January 2008 figure,

then the normal traffic of heavy trucks on the trial road during the six month period after upgrading would have been about 30 per day. The diverted traffic needs to be added to this to give the total heavy traffic. This is shown in Table 7.

**Table 7 Estimates of heavy traffic on the trial road (ADT)**

| **Vehicle type** | July 2005 | July 2006[1] | Dec 2006[1] | Jan 2008[2] |
|---|---|---|---|---|
| | Elapsed time | | | |
| | 0 months | 12 months | 18 months | 30 months |
| Heavy trucks | 10 | 79 | 105 | 41 |

There are a number of potential errors in this calculation.

1. It has been assumed that the diverted traffic begins instantaneously and ends abruptly after six months. It is probably true that it began quickly but it probably tailed off slowly as the road deteriorated.

2. As far as normal traffic (as opposed to diverted) is concerned, the number of heavy vehicles using the south-eastern end of the road was considerably higher than that using the middle section.

3. It is also necessary to add the traffic that traveled during the hours between 06:00hr and 18:00hr.

4. Data concerning the axle loading of the trucks has been obtained from a comprehensive axle load survey that was carried out in March of 2008.

Judgements alone must be used to estimate the likely corrections/adjustments needed to calculate the number of equivalent standard axles that contributed to the rapid deterioration of sections of the road, as follows:

1. No adjustment has been made for the ‘shape’ of the diverted traffic growth and decay.

2. No adjustment is made for varying normal traffic along the road since diverted traffic is dominant and is about twice as much.

3. Heavy traffic at night is assumed to be 50% of day-time traffic, although local hearsay evidence indicates that this may be conservative.

From the axle load survey the average esa per heavy vehicle is about 8.75 standard axles. The level of enforcement of axle load limits is probably quite low in the provinces and so maximum values could be as high as 20 or 30 esa per vehicle, but many will be lightly loaded on a return leg.

Using the data available to date and the assumptions described above, the best estimate of the total number of esa that used the road during the six months that it deteriorated is given by,

Total esa = (Average ADT in period) x (Night correction) x (Days) x (Average esa)

Therefore,

Total esa = 92 x 1.5 x 182 x 8.75
= 220,000 (for six months)

This calculation has been entirely concentrated on the heavy vehicles. The contribution of buses and smaller vehicles, though small, must be added to this figure. It can be seen that the capacity of the road has been greatly exceeded.

## STRENGTH AND PERFORMANCE OF THE ROAD PAVEMENT

If a road behaves badly, there are various possible reasons based on the design, the materials and the quality of construction, or combinations of all three. In order to examine these possibilities it is necessary to estimate the likely traffic capacity assuming that the road was built properly and the materials were satisfactory. This result will then be compared with the estimated capacity based on the as-built properties but assuming that unexpected failure modes do not develop because of material failures (i.e. using actual strengths and as-built thicknesses). Finally, actual behaviour will be examined to identify any failures that cannot be attributed to incorrect design or incorrect constructed thicknesses; in other words, material failures that should not occur if the materials are of adequate strength and the layers have been constructed properly.

A review of the available information from the investigation on pavement condition gave rise to the following key points:

1. Buon Ho road has suffered significant and rapid deterioration leading in places to complete pavement failure.
2. The poor pavement condition was not uniform and there were significant lengths with only slight or moderate deterioration and other areas where no deterioration is evident.
3. Two sections BH5 and BH6 with the same design, but built by different contractors, exhibited markedly different performance characteristics,
4. Sections with the same contractor but different designs exhibited significantly different performance characteristics,
5. The test results for construction materials submitted prior to construction indicated a general compliance with specification. No adverse comments were received from the local supervision team on the subsequently as-delivered materials.
6. Following a site visit during construction, Intech-TRL requested replacement of existing gravel sources with an improved material. Assessment of materials recovered from the inspection pits indicated that this request was not acted upon.
7. In situ and laboratory testing indicated low strength and out-of specification gravel sub-base within sections BH5 and BH6.

8. During the current investigations, visual and laboratory evidence indicated that the as-built Penetration Macadam, WBM and DBM pavement layers contained significant oversize material. There was also evidence in some places of segregation of the fines.
9. Re-assessment of in situ density tests undertaken at the time of construction revealed unrealistic assumptions as to the homogeneity of the density of the compacted material, leading to doubts as to the accuracy of the reported “satisfactory” in situ densities.
10. Visual evidence indicated some variability in the quality of the bitumen surfacing. Laboratory testing indicated a low bitumen content for the Penetration Macadam sections, although this may well be at least partially a result of sampling problems with this form of pavement.
11. Assessment of the layer thickness indicated no significant thinning of the base or sub-base layers beneath carriageway ruts.

In summary, there was significant evidence to indicate that the trial road was, at least in part, constructed with materials that did not meet the specifications and, possibly, to variable compaction standards. The markedly different performance of sections BH5 and BH6, which are nominally the same design but built by different contractors, indicated that the quality of materials and the quality of construction were potentially significant factors.

The original designs are shown in Table 2. Estimates of the likely ‘subgrade’ strength were made by using DCP measurements in the original old road (Figure 2). Analysing the available data using the AASHTO design method it is apparent that even if the road had been constructed as designed, none of the sections would have survived for more than a year or two with the traffic that was being carried after construction (Table 8). However, this conclusion depends on the actual subgrade strength that may differ from the value assumed in the design.

**Table 8 Original thickness designs**

| Section | Chainage | Design Structural Number SNP | Traffic Capacity esa |
|---|---|---|---|
| BH1 | 3.700 – 4.166 | 2.37 | 125,000 |
| BH2 | 5.100 – 5.316 | 2.37 | 125,000 |
| BH3 | 8.600 – 9.100 | 2.37 | 125,000 |
| BH4 | 9.100 – 10.100 | 2.37 | 125,000 |
| BH5 | 10.100 – 12.600 | 2.65 | 265,000 |
| BH6 | 12.600 – 14.980 | 2.65 | 265,000 |

An analysis of the likely traffic carrying capacity of the actually constructed road using the AASHTO pavement design model is shown in Table 9. This analysis takes no account of any weaknesses in the materials in the surfacing or base layers that were removed before the DCP tests were carried out so these traffic estimates are therefore maximum values.

It can be seen from Table 9 that some sections are performing as well as could be expected. These are BH1 and parts of BH 2 and BH 3 and BH 6. The sections that have not performed well are structurally weak and so this performance is also expected. These are parts of BH 2, BH 3, BH 4, BH 5 and BH 6. The only section that appears to be failing despite reasonable strength is part of BH 5. Interpreting data when a section has failed is often difficult because the layers of the pavement will have got weaker and therefore the question of which came first is raised. In this case it is useful to examine the structure more closely of sections that are nominally the same but are performing differently and perhaps the most surprising result is that the variability within sections of the same design is so large.

**Table 9 Buon Ho As Built Traffic Capacity**

| Section | Chainage | Surface/Base | Sub-base | Test Pit | Chainage | Condition Pit | Condition Zone | SNP | Mean traffic capacity (esa) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| BH1 | 3.7 – 4.166 | 60mm of Penetration Macadam | 100mm of WBM | 1 | 3+800 | 2 | 2 | 2.7 | 330,000 | Weak top to subgrade. May fail early under heavy traffic |
| BH2 | 5.1 – 5.316 | 60mm of Penetration Macadam | 100mm of WBM | 2 | 5+070 | 3 | 5 | 3.3 | 1,350,000 | Subgrade of sub-base strength for 270mm |
| | | | | 3 | 5+190 | 4 | 5 | 2.0 | 45,000 | Subgrade 10% |
| BH3 | 8.6 – 9.1 | Double stone chip seal on 100mm DBM | 100mm DBM | 4 | 8+960 | 4 | 5 | 2.25 | 100,000 | Subgrade 12% |
| | | | | 5 | 8+990 | 4 | 5 | 2.9 | 550,000 | Subgrade 13% |
| BH4 | 9.1 – 10.1 | Sand and stone chip emulsion seals on 100mm DBM | 100mm DBM | 6 | 9+935 | 4 | 3 | 1.94 | 40,000 | Base/sub-base 210mm<br>Subgrade 8-10% |
| BH5 | 10.1 – 12.6 | Double stone chip emulsion seal on 100mm DBM | 200mm of natural gravel | 7 | 10+275 | 3 | 3 | 2.83 | 450,000 | Subgrade 13% |
| | | | | 8 | 10+620 | 1 | 2 | 2.3 -3.2 | 100,000 – 1,000,000 | Outside traditional range – Poor sub-base very near surface. Could fail quickly |
| BH6 | 12.6 – 14.98 | Double stone chip emulsion seal on 100mm DBM | 200 mm of natural gravel | 9 | 12+800 | 1 | 1 | 4.35 | 10,000,000 | Strong subgrade |
| | | | | 10 | 14+435 | 4 | 4 | 1.8 | 25,000 | Very thin and weak. Outside the normal boundaries for analysis. Subgrade 11% |

## CONCLUSIONS

Five key questions needed to be addressed by the investigation; as discussed below.

***Was the design suitable for Commune road A traffic***? Taking into account the surveyed strength of the existing gravel road; the current local standard designs and recent SEACAP studies[2] the conclusion may be drawn that the Buon Ho pavement designs were adequate for their original intended purpose.

***Was the road constructed as per specification****?* It is clear from investigations undertaken that some sections of the road were constructed with materials that were out-of-specification and there is a possibility that construction procedures were not fully compliant with those specified.

***Was the as-built road suitable for Commune road A traffic***? From assessments of as-built strength it is likely that some sections of the as-built road would have required periodic maintenance during a 10-year design life.

***Was the design suitable for the actual traffic***? The pavement designs were not suitable for the actual traffic and this would have inevitably resulted in early pavement failure.

***Was the as-built road suitable for actual traffic***? It follows from the above that the as-built road was totally inadequate for the actual traffic.

***What are the key factors causing early deterioration***? Essentially; within 6-7 months the traffic carried by the road was double the 10-year design figure and hence the volume of traffic and its axle loading have far exceeded the design objectives of the road. In the Consultant's opinion it was clear that this was the primary cause of road failure and that if traffic had continued at this volume the whole road it was likely to have been destroyed. However, it was also clear that the rate of this deterioration was aided to some extent by marginal or poor construction in some sections.

It is understood that it is the intention of Dak Lak to upgrade the Buon Ho road to Province Standard. In this case it will be necessary to reconstruct the road to meet Province Road standards of pavement strength and geometry, taking full account of the likely heavy traffic. If the intention is to retain the Buon Ho as a Commune Road then any rehabilitation must be accompanied by stringent measures to restrict large and overloaded trucks.

Vietnam has a rapidly developing economy and this is reflected in the tasks required of Rural Infrastructure networks in different regions and provinces. Analysis of traffic trends in Dak Lak indicates that this province is within a particularly rapidly developing region. Consequently there is a need for a re-assessment of rural road design standards based on the actual and anticipated tasks they will be asked to perform in terms of vehicles, axle loads and traffic volumes, rather than being based on an administrative classification. For example many 'Commune Roads' may indeed be 'Low Volume' but others in some regions, such as Dak lak, certainly are not.

The SEACAP 24 investigations have reinforced the conclusions reached in other SEACAP research that:

1. The role of site supervisors in controlling the contractors' procedures and material usage is not yet generally accepted.
2. Supervisors had a general problem in being able to exert influence on the contractors to abide by specifications.
3. There is a lack of appreciation of the importance of testing as-used materials, in situ testing and daily records.

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[2] SEACAP 3 (Lao) Low Volume Rural Road Standards and Specifications: Part II, TRL Ltd, 2008

4. There is a need to introduce independent check-testing of materials because some provincial laboratories exhibit weak data management control.

Rural roads are valuable assets that require effective management in terms of ensuring that they are not subjected to tasks beyond their design capacity. Light or Low Volume Rural roads are designed and constructed at reduced cost to undertake specific tasks in terms of vehicle type, axle load and traffic capacity and hence a 6T Commune ‘A’ road cannot be expected to undertake the functions of a district or provincial road.

## REFERENCE

SEACAP 24 Webpage: http://www.seacap-info.org/?mod=home&act=pdesc&pid=24

## ACKNOWLEDGEMENTS

This report was produced as part of the SEACAP 24 project contracted to TRL Ltd in principal association with OtB Engineering (International) Ltd. The drafting of the original report was undertaken by Dr Jasper Cook (OtB Engineering) and Dr John Rolt (TRL). Traffic surveying was managed by Mr Bach The Dzung and the Axle Load Survey reported by Mr Heng Kackada (KACE Ltd).

Invaluable support was supplied by the Dak Lak PPMU. David Salter, the SEACAP Programme Manager, provided key facilitation, guidance and programme support.