Scottish Road Research Board

# EARLY LIFE PAVEMENT FAILURES

70072541-002
MARCH 2024

PUBLIC

Scottish Road Research Board

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# EXECUTIVE SUMMARY

As part of the Scottish Road Research Board research and development work, WSP was commissioned to investigate the occurrence of early life pavement defects. The study was split into two phases: assessing the scale of the problem; and site visits to determine causes and potential solutions. The first phase involved collecting Information on early life defects from a range of sources, including Transport Scotland's pavement management system and discussions with Operating Company (OC) representatives. The study covered the Scottish trunk road network that is maintained by the OCs.  The objective of Phase I was to establish the scale of the problem and to identify a list of schemes for further examination. Phase II involved reviewing and visiting schemes identified as experiencing early life defects to identify any common causes or trends.

Transport Scotland's Integrated Road Information System (IRIS) was used to collect construction records on structural maintenance schemes completed between January 2015 to December 2019. The schemes were then cross referenced with post construction defect records held within the routine maintenance section of IRIS. In addition, information relating to early life pavement failures was directly requested from OC representatives.

Category 1 and Category 2 defect data recorded over the five year study period were examined to quantify the number, type and timing of defects over the four geographical areas covered by the OCs. Analysis of the data provided an insight into how structural maintenance schemes deteriorate over time, and how the type and quantity of defects varies across the country. Fretting, cracking and edge deterioration are dominant defects in the northern parts of Scotland, whereas the occurrence of potholes appears to be major defect recorded in the south of Scotland.

The information collected as part of Phase I was used to identify 19 schemes that were deemed to provide useful information on the cause of early life defects. All the sites were visited and inspected, and the findings were analysed along with design scheme data supplied by Transport Scotland. Based on this analysis, the sites were split into four broad groups, namely: external or isolated defect; inadequate inlay depth; edge deterioration and drainage; and urban/utilities. The schemes that fell into these groups were studied to determine the likely reasons that contributed to the early life defects.

Positive outcomes resulting from the site visits included the finding that 42% of the schemes identified in Phase 1 contained only external or isolated defects. Additional analysis on older schemes supported this finding by showing that 30% of schemes constructed in 2015 where a Cat 1 defect had been recorded, required no subsequent  treatment. The latter indicates that apart from isolated surface course defects associated with workmanship the schemes continue to perform well, particularly when surfaced with TS2010. The most commonly occurring defects were associated with inadequate inlay depths, and this was evidenced by the fact that deeper inlays used on the same scheme showed no defects. The observed failures on other schemes were related to inadequate pavement width and drainage, and weak subbase and foundation conditions.

The report discusses the likely failure mechanisms that caused the early life failures on the schemes visited and recommends potential solutions to reduce the incidence of early life defects. General

advice is provided on reducing the risk of early life defects occurring, including optimising the selection of inlay depths, considering deeper construction and avoiding a piecemeal approach.

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# 1

# INTRODUCTION

# 1 INTRODUCTION

## 1.1 CONTEXT

As part of the Scottish Inspection Panel survey in 2019, it was reported that several pothole defects were observed on recently completed surfacing schemes (Figure 1-1). These types of defects are not normally associated with new surfacing and it was recommended that further investigations should be undertaken to investigate whether a problem exists and what measures could be put in place to eliminate any future occurrences.

**Figure 1-1 - Early life defect on one-year-old surfacing**

Around the same time these observations were made, one maintenance scheme in the SW of Scotland started to show localised failures within weeks of being treated. The defects were unexpected and unforeseen, and the pavement had to be partially rebuilt soon after construction. Importantly, no issues or risks were identified at the design stage and the subsequent modes of failure were not anticipated.

Historically, early life pavement defects, such as potholes, are associated with material that is near the end of its service life. Anecdotal evidence suggests that defects associated with new surfacing can be isolated and confined to the surface course, but in some cases the failure can be traced to the bond or breakdown of the material that lies directly below the surface course.

## 1.2 STUDY OBJECTIVES

The study objectives were to:

- establish the scale of the problem by examining defect reports prepared by Operating Companies (OCs) on behalf of Transport Scotland;
- determine the incidence and type of early life defects;
- identify any mechanisms or trends that lead to early life defects and material failure; and
- provide guidance to raise awareness of factors that could potentially contribute to early life material failure.

## 1.3 SCOPE

As part of the Scottish Road Research Board research and development work, WSP was commissioned by Transport Scotland to investigate the occurrence of early life pavement defects. The study was split into two phases:

- Phase 1 – Assessing the scale of the problem
- Phase II – Detailed investigation and guidance

The first phase involved collecting Information on early life defects from a range of sources, including Transport Scotland's pavement management system and discussions with Operating Company (OC) representatives. The study covered the trunk road network, which is maintained by the OCs and is shown in Figure 1-2.

The objective of Phase I was to establish the scale of the problem and identify a list of schemes for further examination.

Phase II examined the identified schemes more closely to identify any common causes or trends. Based on the findings, recommendations were made to mitigate the occurrence of early life pavement failures.

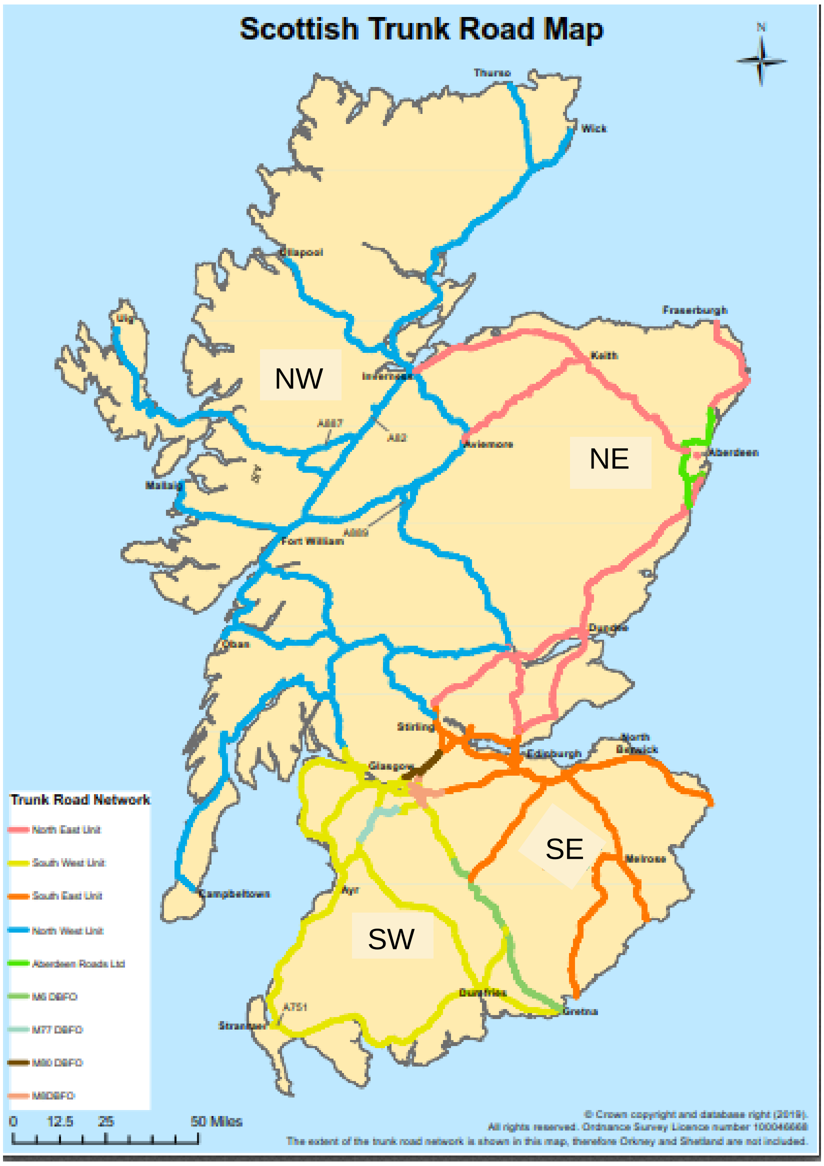


**Figure 1-2 - Scottish trunk road network**

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# ASSESSING THE SCALE OF THE PROBLEM

# 2 ASSESSING THE SCALE OF THE PROBLEM

Information for the study was collected in two ways. The primary source of information was Transport Scotland's Integrated Road Information System (IRIS). In addition, direct requests for information were made to OC representatives for information relating to early life pavement failures. The two data collection approaches and findings are described below.

## 2.1 IRIS

Data on the condition of trunk roads is routinely collected by OCs to ensure that they are safe, efficient and well managed. This information is uploaded to IRIS, which contains several parts. The first step in the data gathering process involved interrogating the Operating Company Pavement Management System (OCPMS) section to extract construction records and scheme extents of all structural maintenance schemes (0100 code). A selected time period of five years was targeted, i.e. January 2015 to December 2019. From this dataset, the scheme extents were cross referenced with post construction defect records held within the Routine Maintenance section of IRIS.

The Routine Maintenance Management function (RMMf) contains information on surface defects that are collected as part of regular inspections and patrols of the trunk road network. It typically covers areas of activity in which work is generally short term and necessary to keep the road network in good working order. Schemes that exhibited insignificant numbers of defects were removed from the analysis at an early stage. This was done to ensure that the search focussed on schemes that contained clusters of defects as opposed to the odd isolated defect.

The Transport Scotland Trunk Road Inspection Manual (TRIM, 2019) sets out the procedures for undertaking inspections, including inspection frequencies, and guidance on defects which should be entered into the RMMf database. Defects are classified into two categories, namely:

- Category 1 – defects that are likely to constitute a danger to the public and road users and require immediate or urgent attention; and
- Category 2 – defects that are deemed not to represent an immediate or imminent hazard, but need to be addressed as part of planned maintenance work.

As the study was focussed on early life pavement failures, which will contain early life defects, a search was carried out for Category 1 and Category 2 defects recorded between 2015 and 2019, i.e. the data search was restricted to pavements between zero and five years old. The data was then broken down further into types of defect (potholes, cracks, fretting, etc), severity (Category 1 or 2) and the four geographical areas covered by the OCs.

### 2.1.1. Cat 1 & Cat 2 defects recorded between 2015 and 2019

The data examined in this section is based on Category 1 (Cat 1) and Category 2 (Cat 2) defects recorded within the boundary of a structural maintenance scheme (known as Series 0100 code). Where the extents of a scheme coincided with locations where defects had been recorded, then a separate list of defects was created and linked to that scheme. The numbers should be regarded as a best estimate as data for some of the schemes was incomplete and this occurred across all the OC units. Examples of incomplete data included missing chainages, transverse lane location, material data, and scheme ID. Any scheme that was incomplete was omitted from the analysis. Other assumptions made during the analysis included:

- Defects
  - Each scheme was examined to identify clusters of defects, i.e. > 1 defect, to determine whether any defects related to surface material were recorded, e.g. potholes, fretting and cracking.
  - Single defects or non-material defects such as cracking around gullies were omitted.
- Chainages
  - In general, all carriageway defects recorded within the extent of a scheme were included in the analysis. However, some defects that were closely located to the periphery or boundary of a known scheme extent were omitted. This was done to provide some allowance for any chainage discrepancies, i.e. overlap between schemes.

Figure 2-1 shows the annual number of structural maintenance schemes (coloured blue) that were completed in each year between 2015 and 2019. The histogram also shows the associated number of schemes where Cat 1 and Cat 2 defects were recorded (coloured red) over the five-year period.

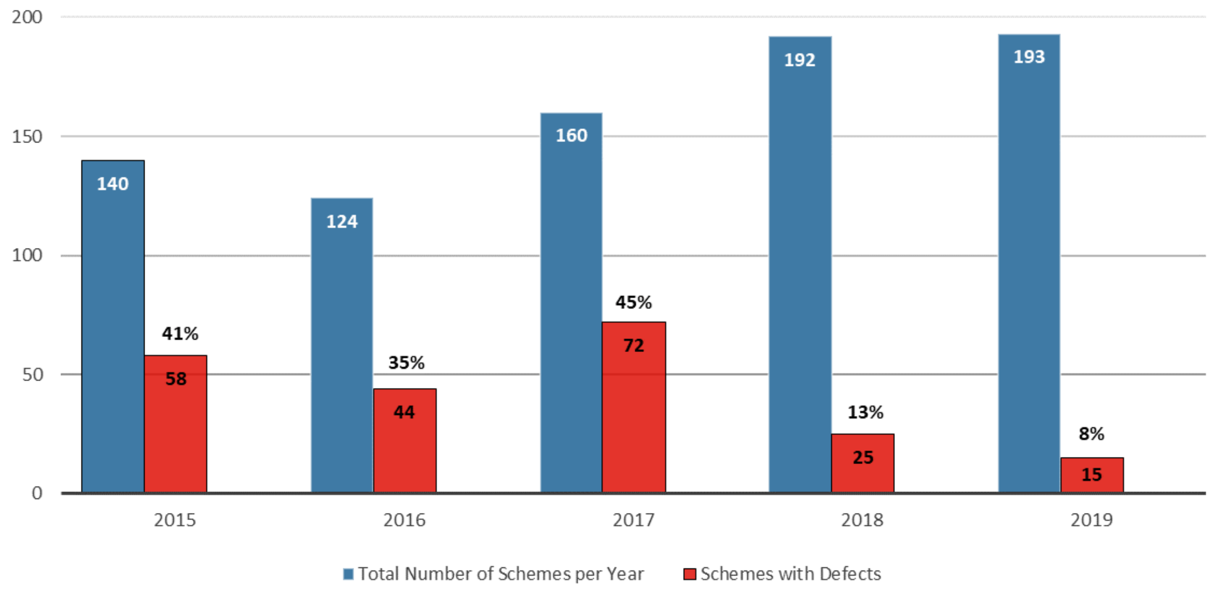


**Figure 2-1 – Annual number of schemes and proportion with defects (2015-2019)**

The number of schemes with defects is aggregated over the five-year period, so it is expected that older schemes will record more defects than the younger schemes. However, it is notable that schemes constructed in 2017 recorded a comparably higher number of defects.

### 2.1.2. Cat 1 defects

The histogram in Figure 2-2 shows the number of schemes that recorded Cat 1 defects over the five-year period. It can be seen that the percentage of schemes with defects has reduced when compared to Figure 2-1, which includes Cat 1 and Cat 2. The figure shows that five per cent of schemes constructed in 2019 exhibited Cat 1 defects, i.e. nine schemes exhibited two or more significant defects shortly after completion and within one year. The graph also shows that 30%, or 42 schemes constructed in 2015 had recorded a Cat 1 defect over the five-year period.

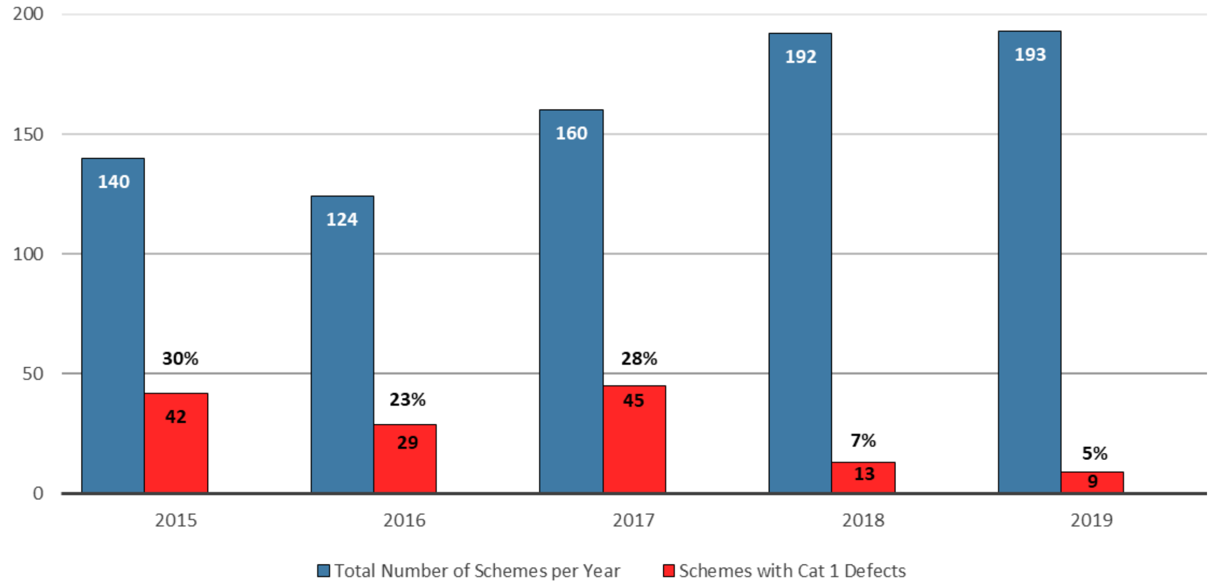


**Figure 2-2 - Annual number of schemes and proportion with Cat 1 defects (2015-2019)**

### 2.1.3. Development of Defects

In an attempt to gauge whether the occurrence of defects has been increasing or decreasing over the five-year period of the study, the database was analysed to determine the number of schemes that recorded Cat 1 and Cat 2 defects within the first year of construction. Figure 2-3 shows the total number of schemes constructed each year along with the number of schemes that recorded Cat 1 defects and the number defect records. In percentage terms, the proportion of schemes affected in the first year ranges between 5% and 11%.

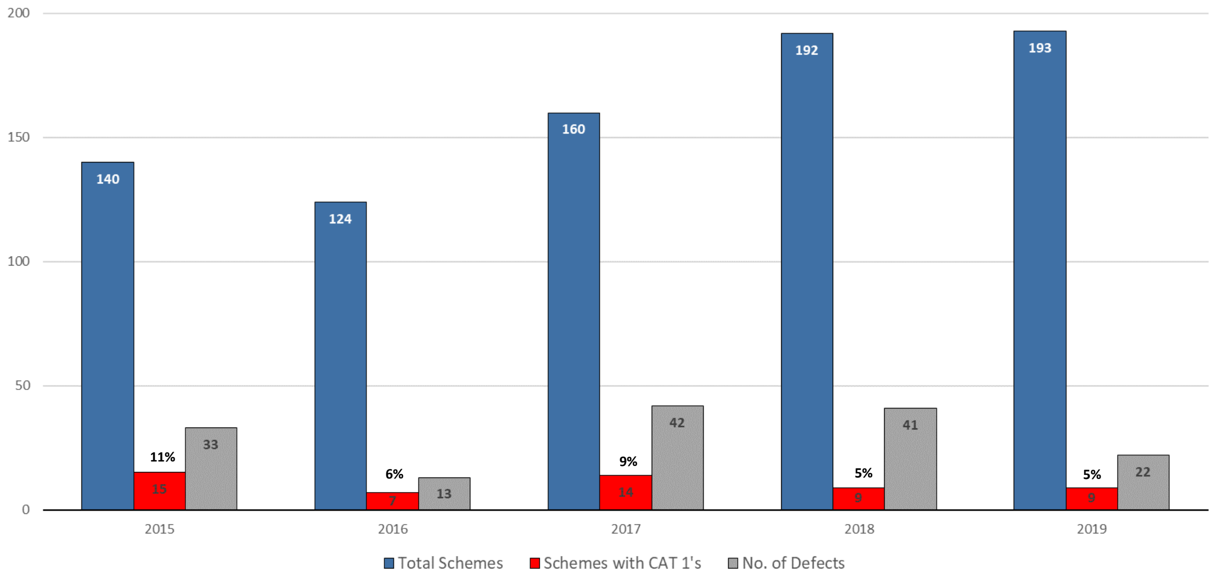

**Figure 2-3 - Cat 1 records in first year of construction (2015-2019)**

Figure 2-4 shows a similar graph for schemes that recorded Cat 2 defects within the first year of construction, including the number of defect records. In percentage terms, the proportion of schemes affected in the first year was slightly higher than Cat 1 ranging between 5% (2019) and 17% (2016).

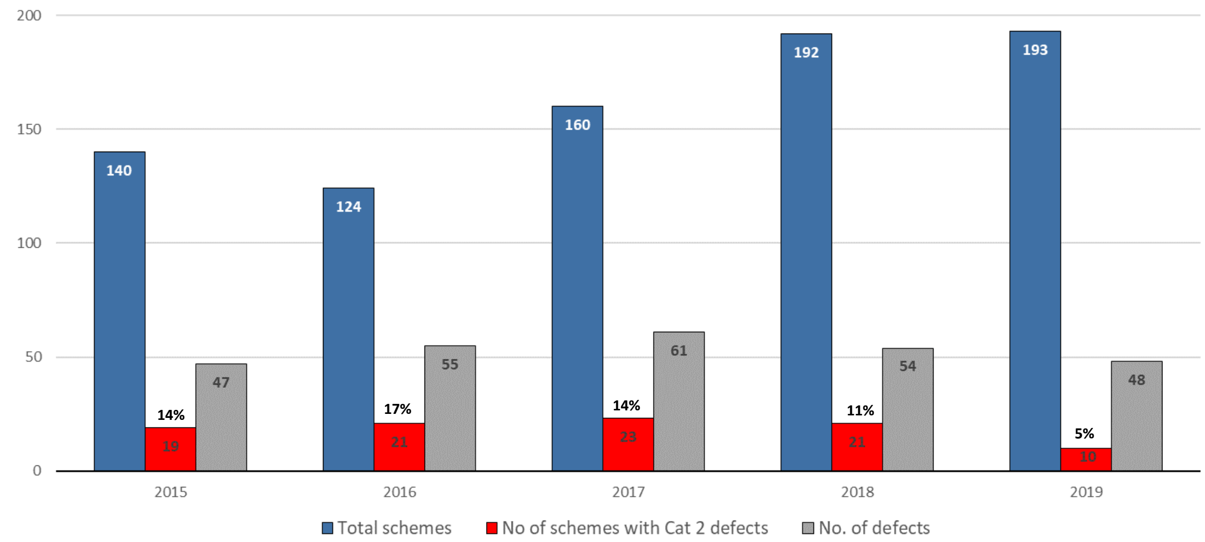


**Figure 2-4 - Cat 2 records in first year of construction (2015-2019)**

The results in Figure 2-4 are interesting in that Cat 2 defects are commonly associated with wear and tear of the road materials and would be expected to occur later in the life of the surfacing. However, Cat 2 defects include faults such as fretting, chip loss and open joints and these are known to occur early in the life of a surfacing.

It was decided to investigate the development of both Cat 1 and Cat 2 defects over the five-year period of the study. The development of Cat 1 and Cat 2 defects is shown in Figure 2-5 and Figure 2-6, respectively.

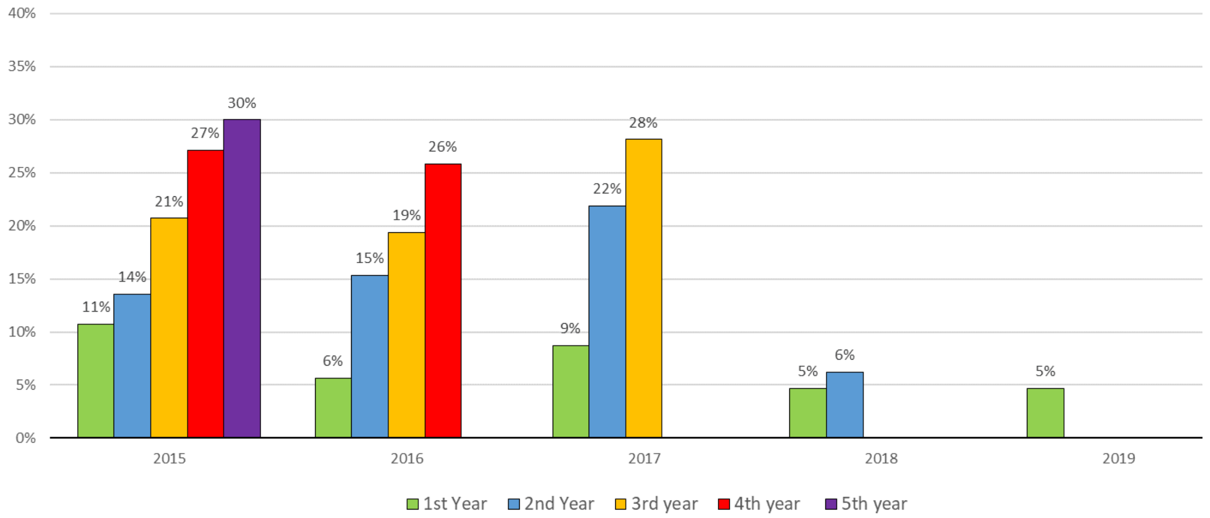

**Figure 2-5 - Yearly development of Cat 1 defects**

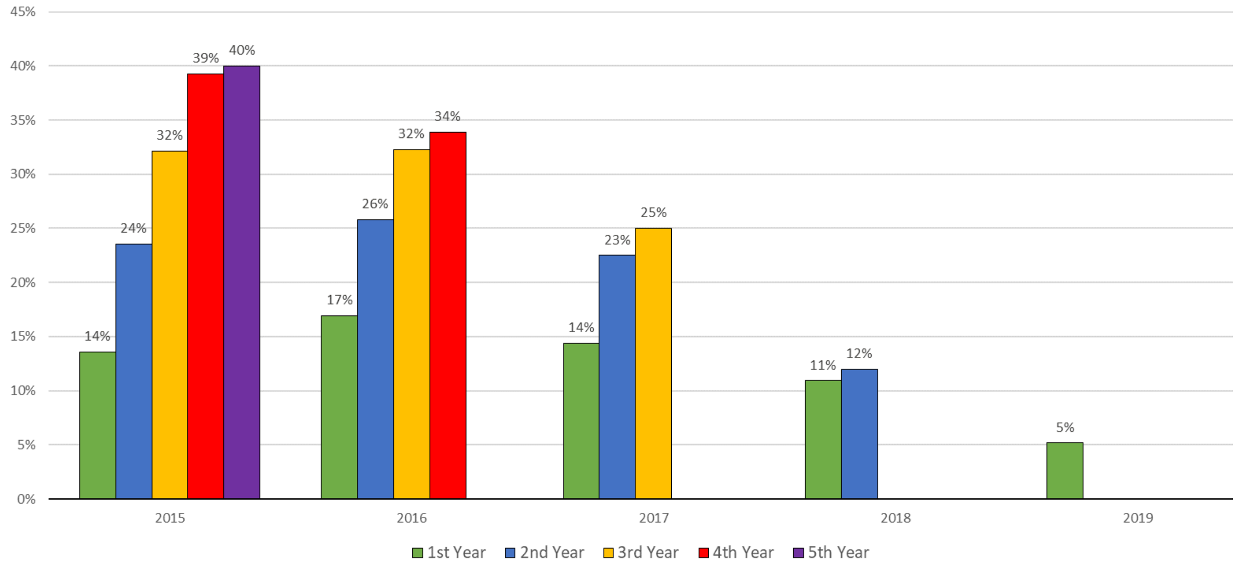


**Figure 2-6 - Yearly development of Cat 2 defects**

The development of the defects can be seen and compared, particularly for the older schemes which possess more data. It can be seen from Figure 2-6 that after five years in service, 40% of the 2015 schemes have recorded Cat 2 defects, this compares to 30% of Cat 1 defects over the same period (Figure 2-5).

### 2.1.4. Cat 1 and Cat 2 defects by OC area

The pie charts in Figure 2-7 and Figure 2-8 show the proportion of Cat 1 and Cat 2 defects recorded in the OC areas between 2015 and 2019, respectively. Figure 2-7 highlights that the highest number of Cat 1 defects was recorded in the SW and the lowest in the NE. Figure 2-8 shows a slightly more even distribution for Cat 2 defects recorded across the trunk road network with the highest number recorded in the NW. However, the picture changes if we look at the number of schemes that contain defects by OC area. Figure 2-9 illustrates the fact that some individual schemes attract a much higher number of defects compared to others, e.g. although the SW attracted the highest number of Cat 1 defects overall, the number of schemes affected was the same as the NW.

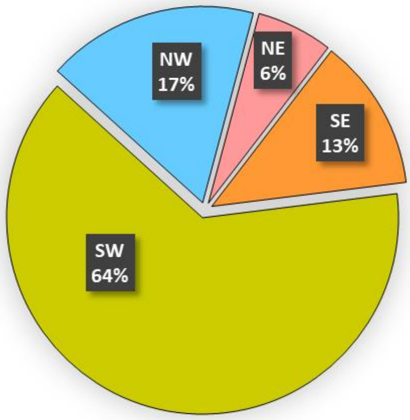


**Figure 2-7 – Proportion of overall Cat 1 defects by OC area**

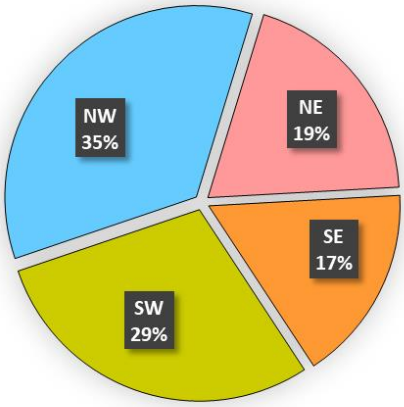


**Figure 2-8 - Proportion of overall Cat 2 defects by OC area**

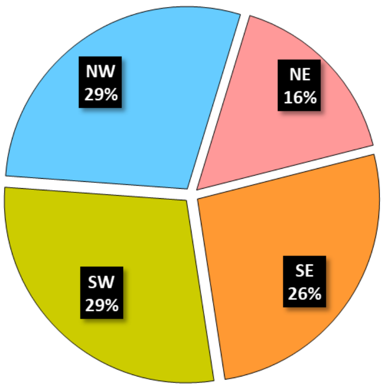


**Figure 2-9 - Proportion of schemes where Cat 1 and Cat 2 defects were recorded**

### 2.1.5. Types of defects

Figure 2-10 shows the type and proportion of surface defects recorded across the entire Scottish road network maintained by the OCs between 2015 and 2019.

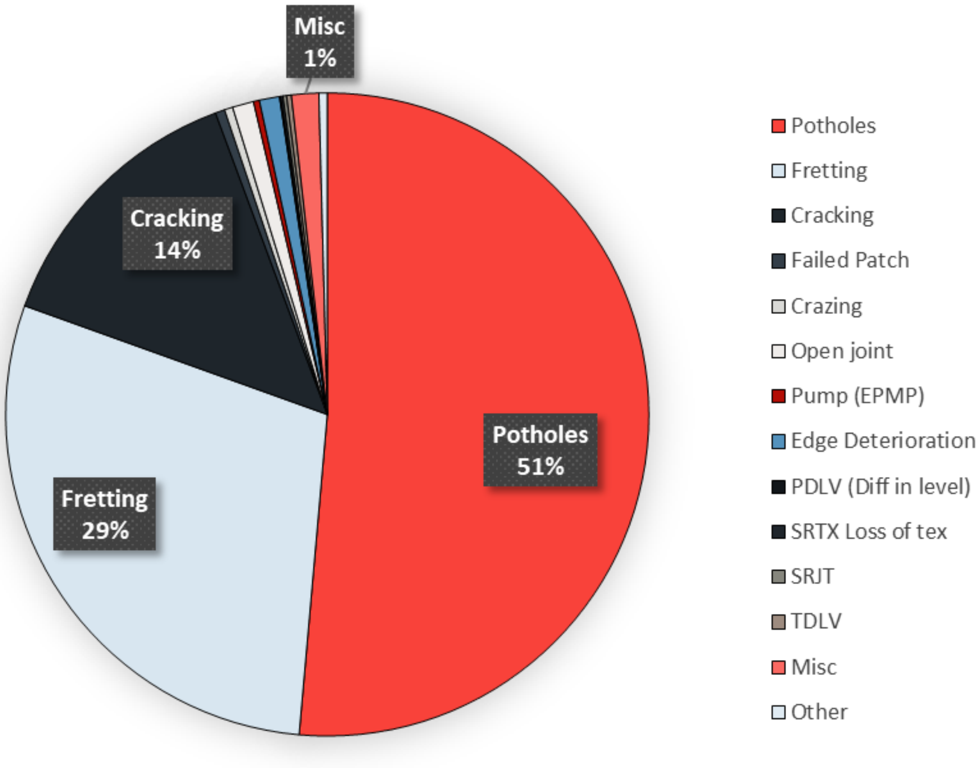


**Figure 2-10 - Breakdown of defect type recorded on entire network (2015-2019)**

To investigate how defect types are influenced by geographical area, i.e. NW, NE, SW and SE, the data collected by the four operating units was separated and is shown side by side in Figure 2-11. It can be seen that both fretting and cracking, and to a lesser extent edge deterioration, appear to be the dominant defects recorded in the northern parts of Scotland. In contrast, the occurrence of potholes is the major defect recorded in the south.

A possible explanation for the increased presence of fretting in the NW and NE could be related to different material configurations. It is known that mixtures with a larger nominal aggregate size (14mm) are more common in the north of Scotland and these materials are known to fret under high stress situations (McHale *et al*, 2017). Cracking and edge deterioration could be related to factors such as narrower road construction, leading to vehicle overrun, and a poorer provision of road drainage. It is unclear why the pothole count is high in the south but it is likely that this could be related to the higher traffic levels experienced in the SE and SW units, which include the main central commuting belt within Scotland.

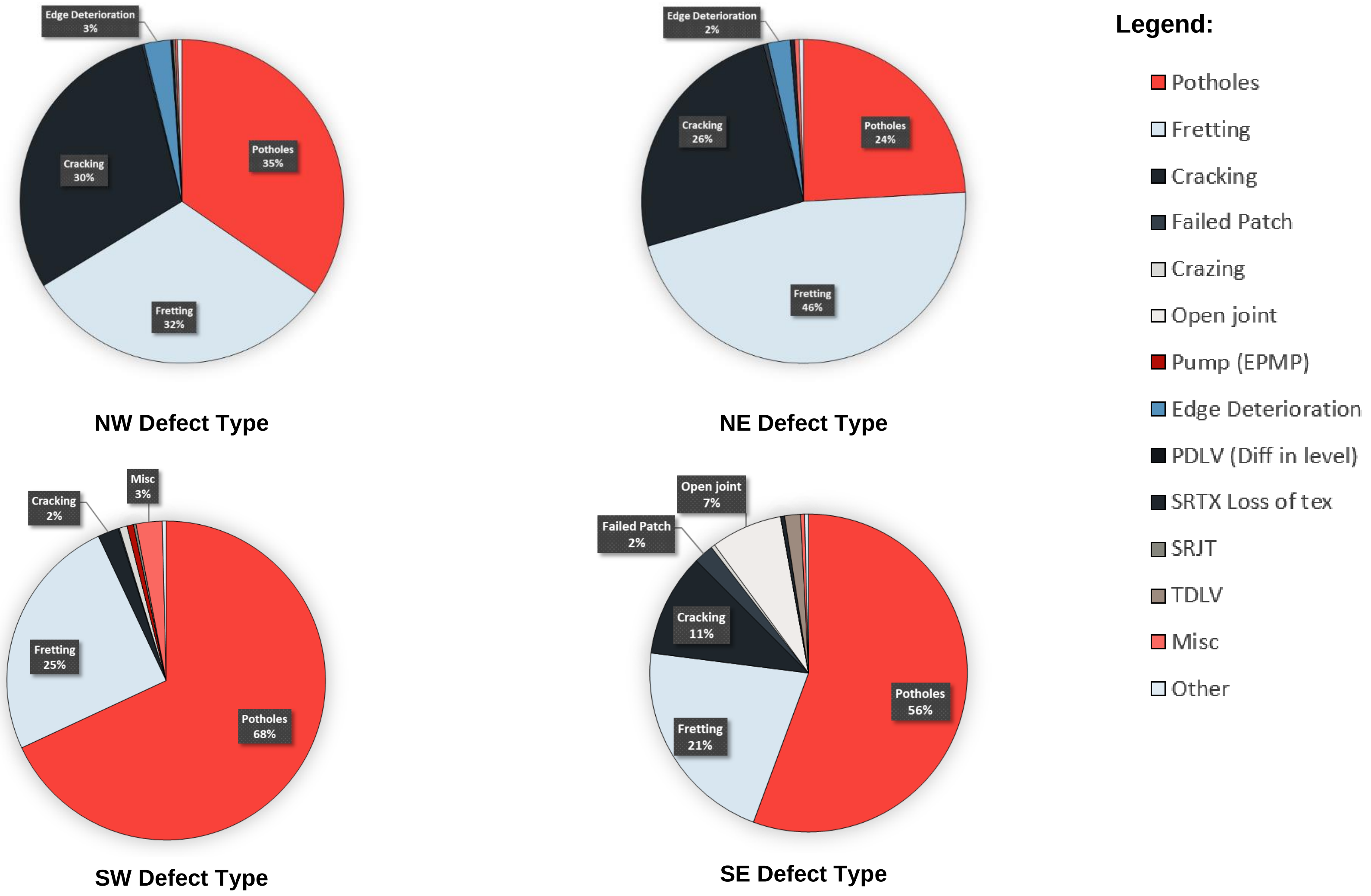


**Figure 2-11 – Proportion of recorded defect types in each OC area**

### 2.1.6. IRIS data summary

Information collected as part of regular inspections and patrols allowed the number, type and timing of defects to be quantified over a five-year period. Analysis of the data also provided some insight into how surfacing schemes deteriorate with time.

Nearly 100% of the Cat 1 defects recorded across the OC operating areas were related to potholes or failed patches which required immediate attention. Figure 2-11 shows that they occur more in the SW of Scotland, with 64% of Cat 1 defects being recorded in this area. However, it is important to note that this high number of Cat 1 defects does not mean that more schemes were affected in the SW than elsewhere, rather some individual schemes in the SW attracted a very high number of Cat 1 defects. It is unclear why the Cat 1 count is so high in the SW, but the wetter climate on the west coast and the fact that the area contains Glasgow, which has the largest traffic volume of Scotland's major cities, may be two related factors.

The descriptions associated with Cat 2 defect records are much more varied and include faults such as fretting (aggregate loss), potholes, cracking, crazing, edge deterioration, open joints and other miscellaneous features. Category 2 defects are not judged to signify an immediate or imminent hazard and are more associated with wear and tear of the road materials. Cat 2 defects picked up early in a pavement's life are likely to provide an indicator of the long term durability of the structural maintenance treatment selected. It is likely that some Cat 2 defects, such as fretting, cracking, crazing and open joints, may provide a precursor to the creation of a pothole or Cat 1 defect at a later stage.

Figure 2-12 highlights that a significant number of Cat 2 defects were recorded as potholes in the SE over the five year period. Across the four OC units, the proportion of CAT 2 defects with the description 'pothole' was small apart from the SE, viz. 6% (NW), 3% (NE) and 8% (SW). It is unclear why the pothole description was used so much in the SE. It is possible that some entries were erroneous or that the inspector deemed certain types of potholes did not pose a risk to road users, but this does not explain the high usage of this type of Cat 2 defect.

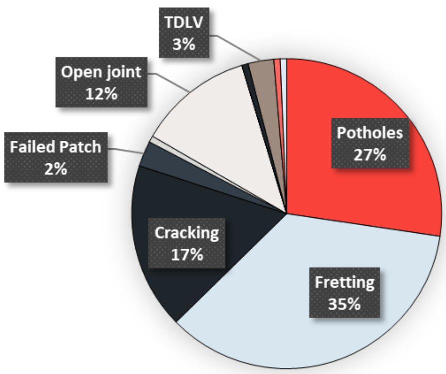


**Figure 2-12 - Type of Cat 2 defects for SE**

Although the incidence of early life defects appears to be relatively low in the first year of a scheme's construction, it is of concern that the defect count increases sharply with time. The data suggests that after five years in service, 40% of the schemes constructed in 2015 had recorded Cat 2 defects, and 30% of the schemes had recorded Cat 1 defects. As Cat 1 defects are repaired quickly, it is expected that the sum of Cat 1 defects should be less than the Cat 2 defect total. Nonetheless, it is of concern that after five years in service that the defect count should be so high.

Analysis of the data showed that the defect count can vary from year to year and that the type and quantity of recorded defects varies across the country. The data showed that the scale or level of deterioration at an individual scheme level can vary considerably, i.e. one scheme may record several defects while others have recorded well in excess of 100 defects. The picture is further complicated by the fact that some scheme defects will be treated and repaired, explaining fluctuations in numbers from year to year. It is also clear that some defects are confined to a small area, whereas others are more widespread throughout a scheme.

In summary, the main findings from the analysis of IRIS are as follow:

*Category 1 defects*

- Nearly 100% of the Cat 1 defects recorded across the OC operating areas were related to potholes or failed patches.
- Over the five-year period Cat 1 defects accounted for approximately half of all the recorded defects.
- Most of the Cat 1 defects (64%) were recorded in the SW of Scotland, although some individual schemes in the SW attracted a very high number of Cat 1 defects.
- The lowest proportion of Cat 1 defects was recorded in the NE of Scotland (6%) with the SE and NW recording 13% and 17%, respectively.

*Category 2 defects*

- Cat 2 defect records are much more varied and include faults such as fretting (aggregate loss), potholes, cracking, crazing, edge deterioration, open joints and other miscellaneous features.
- Cat 2 defects account for 49% of all defects recorded.
- In the SE, 27% of Cat 2 defects were recorded as potholes, this compares to 6% (NW), 3% (NE) and 8% (SW). It is not clear why the high usage of this type of Cat 2 defect was used in the SE.

*Defect types*

- Fretting and cracking, and to a lesser extent edge deterioration, appear to be the dominant defects recorded in the northern parts of Scotland.
- The occurrence of potholes is the major defect recorded in the south of Scotland.

*Development of defects*

- The annual frequency of Cat 1 defects being recorded in the first year of construction for schemes constructed between 2015 and 2019 ranged between 5 and 11%.
- The annual frequency of Cat 2 defects being recorded in the first year of construction for schemes constructed between 2015 and 2019 ranged between 5 and 17%.
- Of the 140 schemes originally built in 2015, 30% had recorded Cat1 defects and 40% recorded Cat 2 defects after five years in service.

## 2.2 CONSULTATION WITH OC REPRESENTATIVES

Requests for information were sent out to the four regional OC units in Scotland, i.e. NW, NE, SW & SE. The OCs were asked to provide any information they had on early life failures that had occurred on recent maintenance schemes (≤ 5 years), including:

- defects that had appeared unexpectedly, particularly within weeks or months of a scheme completion;
- images of defects;
- information on the maintenance scheme that exhibited early life defects, e.g. inlay depth, overlay depth, etc.;
- any comments or observations associated with undertaking remedial work; and
- information on any pavement investigations carried out, including any lessons learnt.

The information provided by the OCs is summarised in Appendix A.

### 2.2.1. Selected early life defect sites

Based on a review of the information supplied by the OCs and additional data held on IRIS, the schemes listed in Table 2-1 were selected as having the potential to provide useful information on the cause of early life defects. The findings of the detailed investigations are discussed in Chapter 3.

**Table 2-1 - Schemes identified for further investigation**

| Area | Scheme ID | Route | Layer date | IRIS defect description |
|---|---|---|---|---|
| NW | 18/NW/0102/006 | A887 | May 18 | Total 37: fretting (37) |
| | 18/NW/0103/095 | A82 | Sep 18 | Total 2: pothole (2) |
| | 16/NW/0103/038 | A82 | May 17 | Total 5: cracking (4) & pothole (1) |
| | 18/NW/0103/133 | A82 | Sep 18 | Total 60: pothole (48) & fretting (12) |
| NE | 17/NE/0103/031 | M90 | Nov 16 | Total 10: fretting (5) & potholes (5) |
| | 17/NE/0103/015 | M90 | Nov 18 | Total 4: pothole (3) & cracking (1) |
| | 17/NE/0103/016 | A9 | Apr 17 | Total 20: pothole (11), fretting (5) & Misc. (4) |
| | 17/NE/0103/018* | A9 | Apr 17 | Total 10: dep (5), potholes (3) & fretting (2) |
| | 18/NE/0103/004 | A95 | Jul 18 | Total 8: edge deterioration (6) & cracking (2) |
| SE | 19/SE/0103/025 | A1 | Nov 18 | Total 6: pothole (5) & open joint (1) |
| | 20/SE/0103/023 | A1 | Aug 19 | Total 3: pothole (3) |
| | 18/SE/0103/049* | A1 | Apr 18 | Total 15: pothole (8), crack/diff (5) & misc. (2) |
| | 17/SE/0103/020 | A7 | Nov 17 | Total 5: pothole (2), fretting (1) & crack (2) |
| | 19/SE/0103/009* | A702 | May 19 | Total 2: pothole (2) |
| | 19/SE/0103/028 | M80 | Mar 19 | Total 4: pothole (4) |
| SW | 18/SW/0103/034* | A77 | Oct 19 | Total 1: pothole (1) |
| | 17/SW/0103/005* | A77 | May 17 | Total 93: potholes (85), fretting (5) & heaving (3) |
| | 19/SW/0103/035* | A77 | Sep 19 | Total 11: potholes (6); fretting (4) & rutting (1) |
| | 19/SW/0103/015* | A737 | Jul 19 | Total 3: pothole (3) |
| | 19/SW/0103/010 | M80 | Sep 18 | Total 6: pothole (6) |

*Key: *Highlighted by OC representative*

# 3

# EARLY LIFE DEFECT SITES

# 3 EARLY LIFE DEFECT SITES

## 3.1 SCHEME INFORMATION

Transport Scotland provided access to information on each of the identified sites listed in Table 2-1, which included:

- general scheme data, e.g. location, length and completion date;
- construction details, including drawings, schematics, treatment type, and maintenance scheme data (MSD) forms;
- defect data, e.g. date identified, location on carriageway and description or type;
- visual condition data on scheme prior to treatment, including core data, visual condition schematics and images;
- visual condition data post treatment; and
- history of any changes to the original design or treatment proposals that were highlighted as part of Transport Scotland's internal review process.

## 3.2 SITE VISITS

All the sites listed in Table 2-1 were visited and inspected, and brief summaries of the site details are provided in Appendix B. The findings of the surveys were analysed along with the scheme data described above. Based on this analysis, the defects within these sites were split into four broad groups:

- External or isolated defect
- Inadequate inlay depth
- Edge deterioration/Drainage
- Urban/Utilities

Figure 3-1 shows the proportion of sites that fell into these four groups and the findings of the site visits under these categories are discussed in more detail below.

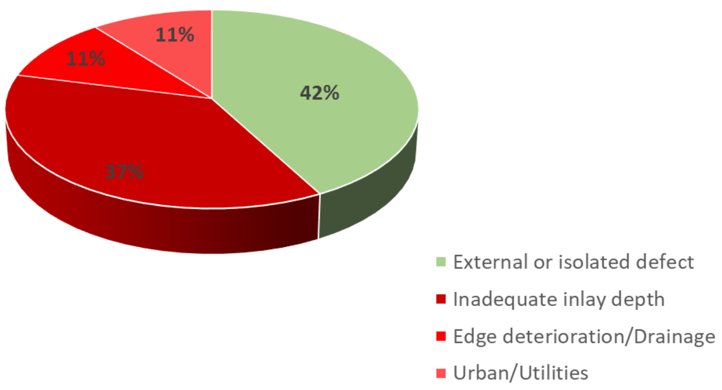


**Figure 3-1 – Summary of site assessment findings**

## 3.3 EXTERNAL OR ISOLATED DEFECT

In general, the site visits confirmed that most of the defects recorded on IRIS could be located during the survey. However, it became clear that in many instances the defects were not directly associated with the maintenance scheme. In reality, the site visits highlighted that the documented defects were just outside or external to the pavement area treated. It was also observed that on some schemes, a single defect or cluster of defects was limited to a very small area. From the 19 sites visited, 8 sites (42%) were assessed to have external or isolated defects.

### 3.3.1. External defects

Five of the schemes visited incorporated a targeted design approach that included treating the pavement to different depths, or no treatment. In the latter case, sections of the pavement within the scheme were not treated and presumably deemed to be defect free at the time of the design. The schemes included both single and dual carriageways. Figure 3-2 shows an example of a section omitted for treatment on a single carriageway scheme. Recorded defects were typically found close to the boundary of these sections, i.e. start, end, or adjacent to longitudinal joints, but external to the treated area. The site visits also confirmed that defects recorded on three schemes were confined to bridge deck areas that had not been treated as part of the maintenance works.

**Figure 3-2 - Example of section omitted for treatment**

### 3.3.2. Isolated defects

Three of the maintenance schemes exhibited defects that were confined to a very small area. These sites were assessed to be in excellent or good condition with the exception of an odd defect or fault.

An example of this type of site is shown in Figure 3-3. The scheme on the A95 near Beith was 868 m long and only one pothole (see insert) was found within the boundary of the treated area.

**Figure 3-3 - A737 Beith with single pothole (18 months old)**

The cause of these isolated defects is often associated with workmanship and quality control during laying operations. For example, it is known that if spills or cold material clumps from asphalt trucks are not removed immediately then these can cause potholes.

## 3.4 INADEQUATE INLAY DEPTH

One noticeable trend from the sites visited was the occurrence of defects in areas where a shallow inlay had been selected. This was evidenced by the fact that deeper inlays used on the same scheme showed no defects. This observation was also verified where deeper inlays had been successfully used to repair failed areas that contained a thin or shallow inlay. Possible failure mechanisms associated with schemes treated with a shallow inlay are discussed below.

### 3.4.1. Weak or damaged substrate

Seven of the schemes visited (37%) exhibited defects in areas where a shallow inlay had been selected in preference to a deeper inlay. The schemes that fell into this category covered the four operating areas. A review of the scheme designs, in combination with observations made from the site visits, suggested that the possible reasons for the early life defects could be due to one or a combination of the following factors:

- Selected treatment depth did not fully remove all of the defective or deteriorated material.
- Planing operations may have left behind a weakened material substrate, i.e. the substrate comprised aged (oxidised) material, possibly containing micro-cracks.
- Insufficient bond existed between the new material and substrate, or substrate and lower pavement layer.

The chosen depth of an inlay is likely to be driven by visual condition surveys (VCS), extracted cores and deflection data, where available. VCS data for one of the schemes visited shows that the main driver for maintenance was surface fretting. Figure 3-4 shows the condition of the surfacing in 2016, prior to treatment in 2017, and Figure 3-5 shows an image taken in 2021, post treatment, at approximately the same location.

**Figure 3-4 - VCS near A9 Dunblane in 2016, prior to treatment**

**Figure 3-5 - A9 near Dunblane after treatment (2021)**

The appearance of the pavement in 2016 shows a fretted surfacing with extensive aggregate loss. It is possible that owing to the porous nature of this surfacing that the underlying layer was exposed to water and weathering effects. It is possible that the removal of this surfacing, by planing to a depth of 40 mm, left behind a weak or weakened substrate. A similar scheme on the A9 near Blackford exhibited similar defects which were replaced with a deeper inlay with no further deterioration occurring.

A scheme visited on the A77 near Maybole had been reported to experience widespread early life defects a few months after completion in 2017. The defects were only found where a 40mm treatment had been carried out, i.e. none of the deeper treated sections of pavement exhibited any defects. An extensive pavement investigation was carried out in 2019 that concluded that the process of milling operations and exposure to light precipitation had activated a clay mineral within the exposed layer or substrate and subsequently affected the bond to the new asphalt layer. The site visit showed that where these areas had been replaced with a deeper inlay the surfacing showed no defects. However, some small areas suspected to still contain a shallow inlay are continuing to deteriorate (Figure 3-6). Three other sites on the A77, A1 and A82 highlighted that the majority of defects were confined to areas where a shallow (40 mm) inlay had been selected.

**Figure 3-6 – Defect on A77 near Drumellan Farm (2021)**

### 3.4.2. Use of thin inlays

A scheme on the A1 involved replacing the failure of a 1 km section of microsurfacing that had begun to delaminate from the surface. The treatment included a 25mm inlay across most of the scheme with a deeper 100 mm treatment over one 150 m section. Shortly after completion in April 2018, defects began to appear in areas that had received the shallower treatment. The site visit in 2021 confirmed that the deeper treatment showed no defects. It was also clear that extensive remedial work (deeper treatment) had been carried out on the site, but the surfacing still appeared to be failing in areas that contained the thin inlay.

Coring data for this site shows that the layer directly below the microsurfacing is a hot rolled asphalt (HRA). The cores show that material layer thicknesses vary, but on average the microsurfacing appears to be around 10 mm thick and the underlying HRA 40 mm thick. Assuming the planing operation was set to mill the material to a depth of 25 mm, it would have left behind a nominal thickness of 25 mm of existing age-old HRA. This is likely to have provided a weakened substrate or support for the newly installed inlay. It is likely that this aged and weakened layer would contain microcracks following milling and constitute a plane of weakness.

It is possible that the new 25mm thick surface course may have slid upon the weak layer below. As a result, excessive flexure in this 25 mm layer would cause the material to crack and break up. An image of the ongoing surfacing deterioration at the A1 is shown in Figure 3-7. Once deterioration commences it is difficult to ascertain the exact failure mechanism, but there are some signs of slippage cracks, represented by crescent-shaped tears, and these are highlighted in Figure 3-7 with dashed red lines. It is likely that the new surfacing material is continuing to move or slide under wheel loads owing to a lack of bond and support from the underlying HRA.

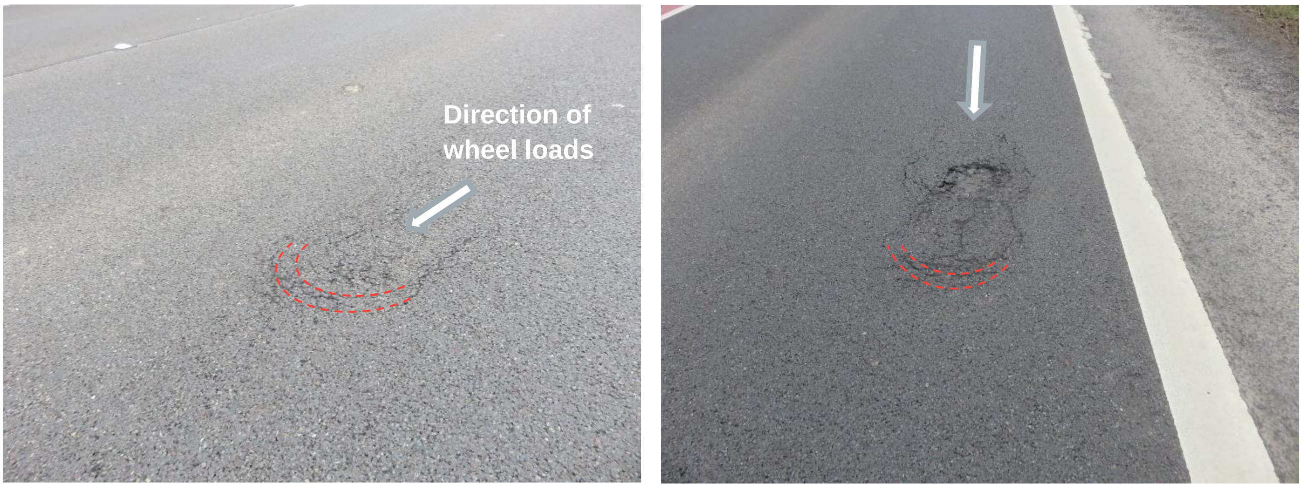


**Figure 3-7 - Development of defects following thin inlay**

## 3.5 EDGE DETERIORATION AND DRAINAGE

Defects at two of the sites visited were predominantly related to edge deterioration. Figure 3-8 and Figure 3-9 show examples of edge deterioration on the A95 and A82, respectively. Heavy goods vehicle (HGV) tyre marks could be seen clearly at both locations.

**Figure 3-8 - HGV edge overrun on A95**

**Figure 3-9 - HGV overrun on A82**

Some of the cracking at the A82 site near Aonach Mòr was more linear in nature and could be due to the presence of a reinforced concrete slab which is located below the upper asphalt layers. However, both these roads comprise long narrow sections (6m width) and will struggle to accommodate two large HGVs passing, particularly if they are carrying a wide load. In addition, both roads provide little lateral restraint in terms of kerbing or drainage. The latter means that they are more vulnerable to edge damage which permits the access of water and further material breakdown.

## 3.6 URBAN/UTILITIES

Two of the sites visited were located in urban areas. Images taken prior to structural maintenance show a high density of utility reinstatements and street furniture. Defects observed during the site visits were related to damage surrounding street furniture and deeper structural damage. Historical images show that treatments to a depth of 250 mm in some areas has not solved the deeper rooted problems. These sites present challenging conditions and it is likely that expensive reconstruction is required, involving the removal of soft spots below the bound layers and possible repairs to utility apparatus.

Figure 3-10 shows images of a section of road in Biggar (A702) before and after treatment. From the design drawings this section received a 220 mm inlay, but it can be seen that this treatment has not prevented the pavement failing under load. This area along with several others showed severe ‘alligator’ cracking which is related to inadequate structural support.  In this instance the reason for failure is most likely due to a loss of subbase or subgrade support, or the presence of water. The presence of water under a pavement will generally cause the underlying materials to become weak.

**Figure 3-10 - Structural rutting before treatment (left, 2018) and after treatment (right, 2021)**

# 4

# DISCUSSION

# 4 DISCUSSION

## 4.1 SITE VISITS VERSUS IRIS

The site visits revealed that 42% of the schemes visited contained defects that were external to the original maintenance works or were isolated defects. The former is related to a limitation in the way that defects are referenced and recorded in IRIS. The latter relates to an exceptional defect that is not representative of the overall condition of the maintenance scheme. These defects were confined to the surface course and are likely to be associated with workmanship or quality control during laying operations. In general, the condition of the TS2010 surface courses was regarded to be good and this finding is in agreement with the results from annual surface course inspections (McHale & Martin, 2019).

Further analysis was undertaken to examine those locations where schemes were constructed in 2015 and Cat 1 defects had been recorded in order to determine whether further treatment was required over subsequent years. The collected data showed that 30% of the sites where CAT 1 defects had been repaired required no further maintenance treatment. This provides additional evidence that supports the site visit observations, i.e. that the recorded defects were exceptional and did not represent the overall condition of the maintenance scheme.

Figure 4-1 shows that if the above findings were applied as a general correction factor, then it would significantly reduce the apparent incidence of early life defects. For schemes originally completed in 2015, the incidence of Cat 1 defects occurring within the extents of a maintenance scheme would fall from 30% to 17% after five years in service. A similar exercise would show that the incidence of Cat 2 defects falls from 40% to 24%. Similarly, the annual frequency of Cat 1 defects recorded in the first year of construction falls from 6% to 3% and from 11% to 5% for Cat 2.

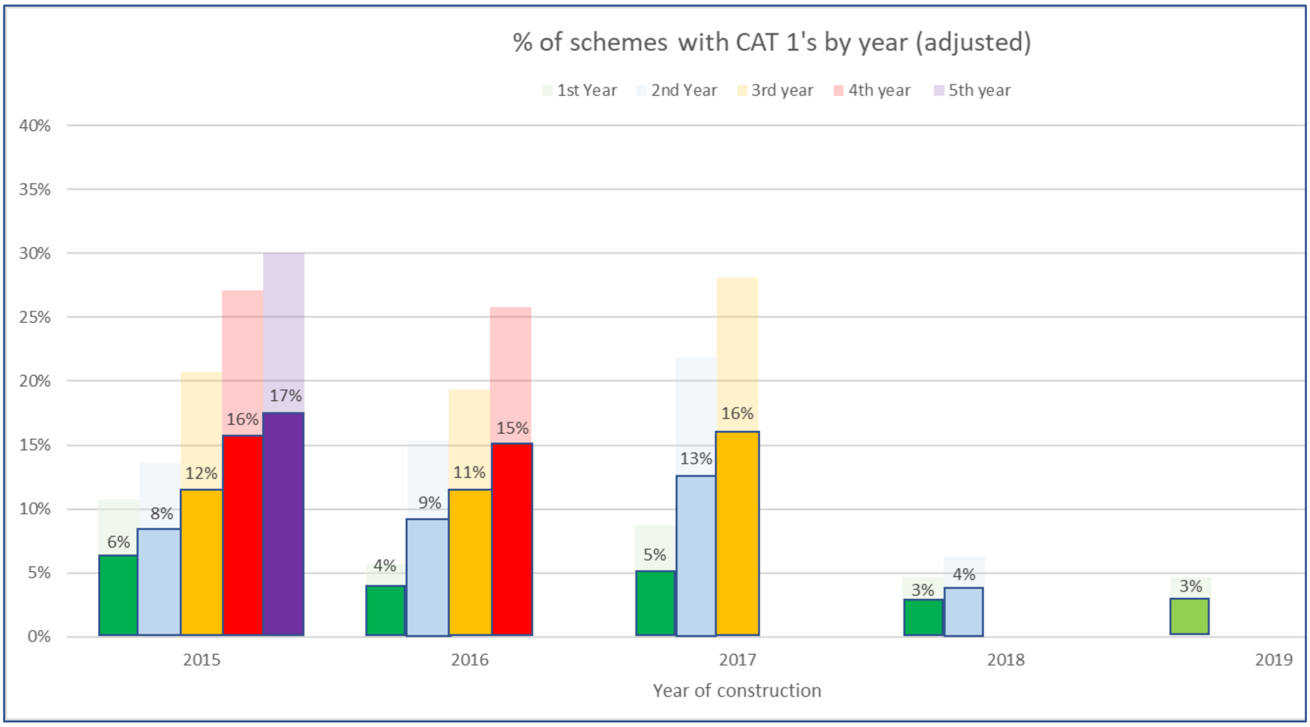


**Figure 4-1 - Schemes constructed in 2015 with correction factor applied**

## 4.2 DETERIORATION MECHANISMS

### 4.2.1. Substrate condition

The most common early life defects were associated with inadequate inlay depth. This was evidenced by the fact that on several schemes that contained both shallow and deeper inlays, the defects were confined to the shallow inlays. From failure investigations carried out on some of the schemes that exhibited extensive defects, it had been speculated that some of the exposed substrates, following milling, had undergone some form of deterioration, on exposure to rainfall. The inference here, is that the substrate was deemed to be in an adequate condition to receive the inlay treatment, but owing to unforeseen conditions the inlay subsequently failed following opening to traffic.

It is possible that rainfall could contribute to the breakdown of an old milled material substrate, but it is contended that the primary cause of failure on these schemes is related to the existence of a poor or unstable substrate. The surface of the substrate that directly supports an inlay needs to be in good condition and have adequate thickness to ensure satisfactory bond with the new inlay material and the pavement layer directly below. If the material condition of the substrate layer is poor, prior to or post milling, it will be unable to support the new inlay material and breakdown under traffic loads. Similarly, if the substrate layer comprises a thin lens or slivers of material it will not provide adequate bond or support to the new material. In either scenario the inlay material will not be adequately supported by the underlying substrate layer and insufficient bond will result in shear leading to excessive flexure of the inlay which will cause the material to crack. The latter will permit the access of water and subsequent deterioration is likely to take the form of potholing.

### 4.2.2. Inadequate width and drainage

Following a review of scheme documentation, several references are made to ‘evolved roads with limited drainage’. This description is typically used to describe a trunk road that has not been designed (or constructed) in full compliance with normal UK standards, such as the DMRB. Typically, these roads comprise non-standard geometry and layout, e.g. horizontal and vertical alignment, width, drainage, etc. In certain instances, the existing road layout and geometry does not permit some HGV traffic to pass without incurring vehicle overrun at the edge of the road pavement. In general, many of these roads are not kerbed meaning that there is little lateral restraint, and the consequence is that the pavement breaks or cracks at the edge. Drainage on these roads can also only be described as rudimentary. It is highly likely that where standing water is allowed to accumulate at the edge of the pavement this will exacerbate the situation and result in localised areas of structural failure.

### 4.2.3. Urban environment

Owing to the presence of utility apparatus, urban environments present challenging conditions to carry out structural maintenance. Street furniture, utility trenches and reinstatements increase the roughness of road pavements. They also introduce discontinuities in the pavement structure, which can affect the pavement's expected life span. For the two sites visited as part of this project, two main types of deterioration were noted: functional and structural. The former relates to loss in profile owing to rocking street furniture and subsequent surface defects. However, it should be noted that loss of profile can result in dynamic effects increasing loads on the pavement that can lead to structural failure. The latter relates to sections of the pavement where large deflections or deformations have occurred owing to the existing pavement structure not being adequately supported at depth.

On one of the schemes, small targeted sections received inlays to a depth of 250 mm. The fact that some of these area have continued to fail following treatment suggests that the material directly below is soft or weak and needs to be replaced.

## 4.3 POTENTIAL SOLUTIONS

### 4.3.1. Optimising inlay depth

The surface course of a road pavement is commonly replaced or treated owing to some form of deterioration, such as polishing, fretting, cracking and poor profile. Dependant on the condition of the pavement and height restrictions, the existing surface is commonly removed by milling, or cold planing, and replaced with new asphalt in a process which is called an inlay. In terms of efficiency, there is a good case to minimise the thickness of an inlay as it reduces both material and energy costs. The availability of modern surfacing that makes use of smaller aggregate sizes and high binder contents, also means materials can be successfully laid and compacted in thinner layers.

This study has highlighted that the benefits of shallow inlays, i.e. less than 100 mm, need to be balanced against the risk of an early life failure. There is a real risk that a shallow inlay may not be the most appropriate choice if the stability of the substrate is compromised. The substrate needs to be in a sound condition and provide adequate bond with both the inlay material and the pavement layer directly below. A review of the available design data used in this study suggests that core data is not sufficient in itself to determine whether the milled substrate will be sound. However, material thicknesses from the extracted cores can be used to predict where the proposed inlay will sit within the treated pavement.

Where an existing surface is being replaced to a depth of 50 mm thickness or less, special care needs to be taken to ensure that the condition of the substrate is sound. The following factors should be taken into account when proposing a shallow inlay.

*Assessment of deteriorated surface course*

Fretting and ravelling of modern surface courses are recognised to be the most common distress mechanisms. The process involves the progressive loss of fine mortar and aggregate from the surface of the mixture owing to the action of trafficking and weathering. These materials commonly present an open and porous appearance. When this type of material is being replaced, consideration should be given to the possibility that owing to its higher permeability, water infiltration and water retention may have caused a partial breakdown of the layer below.

Similarly, attention should be given to other surfaces that are badly cracked and the possibility that the lower layer has undergone some deterioration.

*Substrate thickness*

It is important that the in situ substrate thickness is not too thin. The substrate thickness can be estimated by subtracting the proposed inlay depth from the top of the original surface and measuring the distance to the next layer interface. If the thickness is less than 25 mm, consideration should be given to increasing the inlay depth.

*Inspection of milled substrate*

It is essential that all defective material is removed to provide a sound, uncracked surface to which the new asphalt can firmly bond. This is to prevent any defective residual material affect the performance of the treated pavement.

The condition of the of milled surfacing should be inspected thoroughly following brushing and prior to surfacing operations. It is essential that lenses or slivers of asphalt are not present on the planed surface as these could present potential slip planes at the interface with the new asphalt. If it is not possible to examine the surface properly, e.g. night-time working, then consideration should be given to increasing the inlay depth.

It should be noted that a greater inlay thickness, i.e. ≥ 100 mm, will reduce the stresses at the interface of the substrate. Dependant on the degree of deterioration and the depth relative to the new surface, the risk of failure of a sub-standard substrate is significantly lower when located lower in the pavement. For this reason, if any of the factors described above cannot be evaluated then increasing the inlay depth will result in a lower risk of early life defects.

### 4.3.2. Non-standard designs

Two of the schemes visited displayed significant defects at the pavement edges after 2.5 years. One of the sites on the A82 near Aonach Mòr received extensive treatment. The entire site was milled to a depth of approximately 150mm and then replaced, with 50mm of AC20, a pavement reinforcement system (Tensar), 60mm of AC20 and final 40mm of SMA. The design was developed to address the presence of a reinforced concrete slab which had been discovered at depth and which had caused transverse cracking and the breakdown of the original overlying asphalt.

At the time of the visit several defects were noted which were confined to the outer edge of the pavement and could have been related to the edge of the lower concrete slab. However, some of the defects were observed to be of a structural nature (see Figure 4-2). This road is a rural single carriageway with an average width of 6.1m and limited drainage. It is recognised that these types of road are not uncommon on the Scottish network and it is possible that some pavements perform better than others owing to the presence of natural free draining and favourable ground conditions. Nonetheless, it is recommended that where excessive vehicle overrun and damage is identified at the design stage, then road widening and improved drainage must be considered. Notwithstanding the adoption of this advice, it should be expected that the life span of these type of roads will be shorter than would otherwise be the case and hence the appearance of early life defects will continue to occur.

**Figure 4-2 - Structural failure noted on A82 at 2.5 years old**

### 4.3.3. Urban environment

Carrying out structural maintenance on a road pavement that has failed owing to a high density of utility apparatus, reinstatements and street furniture is challenging. There is a high likelihood that many of the surface defects encountered in an urban environment are due to failure of material below the bound layers of the pavement. One site visited as part of this study (Figure 4-3 and Figure 4-4) suggests that full reconstruction in some sections may be the only solution. Full reconstruction requires the replacement of all the bound layers and may extend into the foundation. It is likely that subbase defects, such as low CBRs, contamination, etc, mean that the subbase may need to be replaced.

**Figure 4-3 - Structural failure on A702 after 22 months**

**Figure 4-4 - Alligator cracking and remedial treatment at A702**

### 4.3.4. Targeted treatment

It was noted during the site visits that some sections of pavement within a maintenance scheme were not treated, and this observation related to both single and dual carriageway schemes. It is assumed that these sections of the pavement were deemed to be defect free at the time of the design. Owing to budgetary constraints it may appear attractive to 'sweat the asset' or make best use of what already exists. However, there remains a real risk that owing to the age of the surfacing left in place, subsequent deterioration will lead to water infiltration and water retention that could cause damage to the lower layers.  It is recommended that the age, type and typical service life of the surfacing should be considered, and if the material is within two or three years of its predicted service life it should be replaced.

# 5

# CONCLUSIONS & RECOMMENDATIONS

# 5 CONCLUSIONS & RECOMMENDATIONS

## 5.1 IRIS

The IRIS database was examined to provide an indication of how structural maintenance schemes perform over a five year period following completion. Information collected as part of regular trunk road inspections was analysed to estimate the number, type and timing of defects recorded between January 2015 and December 2019. Cat 1 defects are typically associated with potholes and failed patches. Cat 2 defects are much more varied and include faults such as fretting, cracking, edge deterioration and other miscellaneous features. Category 2 defects are not judged to signify an immediate or imminent hazard and are more associated with wear and tear of the road materials. The findings of the analysis were as follows:

*Occurrence of defects on structural maintenance schemes*

- The annual frequency of Cat 1 defects being recorded in the first year of construction for schemes constructed between 2015 and 2019 ranged between 5 and 11%.
- The annual frequency of Cat 2 defects being recorded in the first year of construction for schemes constructed between 2015 and 2019 ranged between 5 and 17%.
- From the 40 schemes built in 2015, Cat 1 and Cat 2 defects were recorded within the same scheme extents after five years of service in 30% hand 40% of cases respectively.
- Fretting and cracking, and to a lesser extent edge deterioration, appear to be the dominant defects recorded in the northern parts of Scotland.
- The occurrence of potholes was the main defect recorded in the south of Scotland.

## 5.2 EARLY LIFE DEFECT SITES

Based on a review of IRIS and information supplied by OCs, 19 schemes were identified as having the potential to provide useful information on the cause of early life defects. All the sites were visited and inspected, and the findings were analysed along with design scheme data supplied by Transport Scotland. Based on this analysis, the sites were split into four broad groups, namely: external or isolated defect; inadequate inlay depth; edge deterioration and drainage; and urban/utilities. The schemes that fell into these groups were studied to determine the likely reasons that contributed to early life defects. The main findings were as follows:

- The site visits highlighted that 42% of the schemes where defects had been recorded within the scheme extents contained defects that were external to the original maintenance works or were isolated defects.
- Additional analysis corroborated the above finding by showing that 30% of schemes constructed in 2015 where a Cat 1 defect had also been recorded, required no further maintenance treatment following repair of the CAT 1 defect.
- When the findings from Phase 1 (using IRIS database) are adjusted for external and exceptional defects, the incidence of Cat1 defects coinciding with maintenance schemes falls from 6% to 3% after one year and 30% to 17% after five years.
- The condition of surface courses, particularly TS2010, was regarded to be good.
- The most common early life defects were associated with inadequate inlay depth and this was evidenced by the fact that deeper inlays used on the same scheme showed no defects.

- For schemes treated with shallow inlays the available information suggested that the primary cause of failure was related to poor substrate stability.
- The failure at some schemes was related to inadequate pavement width and drainage.
- Information collected on urban schemes suggested that full reconstruction was required in some instances and that defects were due to weak subbase and foundation conditions.

## 5.3 RECOMMENDATIONS

Section 4 of the report discusses the likely failure mechanisms that caused the early life failures on the schemes visited and recommends potential solutions to reduce the incidence of early life defects. General advice is provided on reducing the risk of early life defects occurring, including optimising the selection of inlay depths.

It is also recommended that the site on the A82, near Aonach Mòr, be monitored to determine the ongoing performance of pavement reinforcement geogrid.

# 6 REFERENCES


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**TRIM (2019).** *Transport Scotland Trunk Road Inspection Manual*. Transport Scotland, Buchanan house, Glasgow.

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# Appendix A

## OC INFORMATION

## A.1 South West Unit

A defect register, listing 28 schemes, was submitted by the SW representative. The list contained information on the sites and some of the defects that had been recorded between 2015 and 2019. Fourteen of the scheme identifiers were coded ‘0300’ signifying that the work was carried out as part of routine maintenance. The other 14 schemes were coded ‘0100’ which means they were part of a structural maintenance programme. A decision was made to concentrate on the latter sites as these schemes require to be designed and were likely to provide more relevant information to the study. Some images of the early life failures are shown in Figure A-1.

**A77 Whattriggs(SB)**

**A77 Drumellan Farm**

**Figure A-1 - Images of early life failures in the SW**

The OC highlighted some general recurring themes associated with the early life defects:

- defects can appear within weeks of surfacing;
- defects were mostly localised and didn’t appear to be ‘traditional’ surface defects;
- all defects were in areas which only received a surface course replacement; and
- there were no indications of structural failure in the lower layers prior to surfacing.

Table A-1 shows the name of the structural maintenance scheme submitted, date completed, and if additional information was provided. The schemes were also cross-referenced with data held on IRIS and the last column shows the recorded number of defects for the scheme.

**Table A-1 - SW schemes with early life defects**

| Scheme name | Date laid | Other Information (OC) | No. of recorded defects (IRIS) |
|---|---|---|---|
| A77 Sandyford to St Quivox | 01/03/2015 | - | Total 18: potholes (13) & fretting (5). |
| M8 Jct 31 EB | 17/05/2015 | - | Total 13: potholes (10) & fretting (3). |
| M74 Blackwood NB | 22/06/2015 | Potholes, material type, images | Total 139: potholes (119); fretting (12); pumping (5); cracking (2); & joint (1). |
| A77 Minishant | 11/10/2015 | Material type | Total 110: potholes (81); heaving (10); depression (10); various (5); & chip loss (4). |
| A77 South of Ardwell Farm | 07/11/2015 | Crazing | Total 57: potholes (35); fretting (19) & heaving (3). |
| A77 Drumellan Farm | 04/05/2017 | Pavement failure report | Total 93: potholes (85): fretting (5) & heaving (3). |
| M80 Jct 2 NB | 21/06/2017 | Material type | Total 18: potholes (18). |
| M80 Jct 2 SB | 16/09/2017 | Material type | Total 7: potholes (4): fretting (2) & open joint (1). |
| A77 Ballantrae | 06/12/2018 | Displacement & cracking, material type, laying data/conditions | Total 6: fretting (5) & heaving (1). |
| A737 Roebank to B777 | 07/08/2019 | Displacement & cracking, material type, laying data/conditions | Total 2: potholes (2). |
| A77 Dalquat to Minnybae | 26/10/2019 | Pothole with cracking, material type, laying data/conditions | Total 3: potholes (3) |
| A77 Whattriggs to Inchgottrick (SB) | 05/08/2019 | Pothole with cracking, material type, laying data/conditions | Total 13: potholes (6); fretting (6) & rutting (1). |
| A75 Halfway House | May 2019 | - | Total 2: crazing (2) |
| A75 Muirfad | July 2019 | Potholes, material type (*defect reported August 2020) | *No IRIS data found* |

The SW schemes above represent 25% of the structural maintenance schemes on IRIS that recorded Cat 1 and Cat 2 defects between 2015 and 2019.

## A.2 South East Unit

A defect register, listing 5 schemes, was submitted by the SE unit representative. The schemes are listed in Table A-2. All the schemes were part of a structural maintenance programme and coded ‘0100’. An image of an early life failure for one of the schemes is shown in Figure A-2.

**Table A-2 - SE schemes with early life defects**

| Scheme name | Date laid | Other Information (OC) | No. of recorded defects (IRIS) |
|---|---|---|---|
| A720 Lothianburn to Dreghorn (WB) | 03/09/2015 | Potholes in wheel track | Total 27: potholes (13); fretted areas (5); cracking (6): & open joints (3). |
| A1 Brockholes | 23/04/2018 | Investigation report | Total 15: Potholes (8), some recorded as multiple; cracking/difference in level (5); & trenching (2). |
| A1 Wallyford to Dolphinston (SB) | Nov 2018 | Two potholes or depressions with cracking, images | Total 6: potholes (5) & open joint (1). |
| A702 Bigger High Street | May 2019 | Single pothole, image | Total 2: potholes (2). |
| A1 Gladsmuir to Bankton (NB) | Aug 2019 | Single pothole, image | *No IRIS data found* |

The SE schemes above represent 10% of the structural maintenance schemes on IRIS that have recorded Cat 1 and Cat 2 defects between 2015 and 2019.

**A1 Brockholes**

**Figure A-2 - Early life defect in the SE**

## A.3 North East Unit

Only one scheme was identified by the NE unit and the information is summarised in Table A-3. The OC highlighted that they had been experiencing some early life joint failures but these had been rectified by the laying contractor once identified.

**Table A-3 - NE schemes with early life defects**

| Scheme name | Date laid | Other Information (OC) | No. of recorded defects (IRIS) |
|---|---|---|---|
| A9 Blackford (NB) | April 2017 | Initially appeared as rutting, core report. | Total 8: Depression (3); potholes (2); fretting (2) & failed repair (1). |

The NE scheme above represents 3% of the structural maintenance schemes on IRIS that have recorded Cat 1 and Cat 2 defects between 2015 and 2019. An image of the early life failure for the Blackford scheme is shown in Figure A-3.

**A9 Blackford (NB)**

**Figure A-3 - Early life defect in the NE**

## A.4 North West Unit

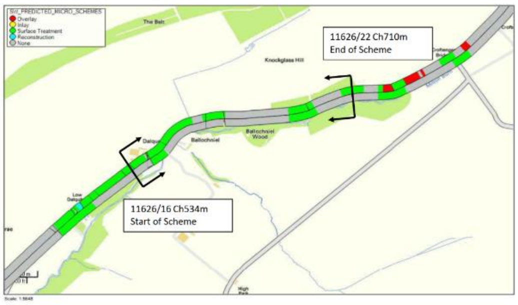
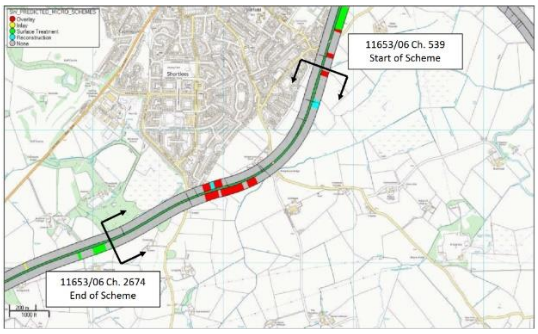
No information was submitted by the North West Unit. According to IRIS, 56 schemes recorded Cat 1 and Cat 2 defects between 2015 and 2019.

# Appendix B

## SITE DETAILS

Public

## B.1 SW Survey Sites

| Site no. | Scheme ref | Location/ Survey action | Description/Scheme design notes |
|---|---|---|---|
| 18 | 18/SW/0103/034 | <br>• Walk-over, check current status | A77 - South of Kirkoswald<br>Road Type: D2; length 846m; completed in October 2019.<br><br>This scheme was supplied by the OC, highlighting a large pothole with cracking in the vicinity and water within the hole. The description and location appear to correspond with the defect at chainage 217 found as part of this investigation. The treatment, from analysis of the VCS and cores appears to be reasonable, but there is no client review within IRIS to ascertain any concerns or conflicts arising from the review process. |
| 20 | 17/SW/0103/005 | <br>• Walk-over, check current status | A77 – Drumellan Farm.<br>Road Type: S2; length 1200 m; completed in May 2017.<br><br>93 defects on this scheme have been well documented with further coring and laboratory testing to ascertain the route problem. The treatment proposed by the OC appears to have been reasonable, with a 40mm inlay implemented through the majority of the scheme with targeted 200m inlays dictated by the VCS and core reports. IR highlighted issues with the existing binder course, possibly suffering from moisture ingress when exposed following planing operations. The presence of clay was found in the binder course. Construction failures were restricted to sections that had received a 40mm inlay. |
| 19 | 19/SW/0103/035 | <br>• Drive-over, check current status<br>• Closer inspection to be carried out at Laybys (one located at beginning of job)<br>• Defects/repairs located near overbridge | A77 (SB) - South of Kilmarnock.<br>Road Type: D2; length 2135 m; completed in September 2019.<br><br>Scheme supplied by OC. Eleven defects include potholes, fretting and chip loss. Street View (Sept 2020) shows variation in surface texture between CL1 & CL2 with the former looking very open compared to CL2. Scheme includes 40 mm to 220 mm structural inlays. |

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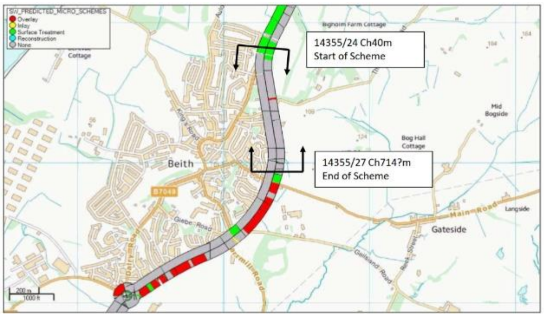
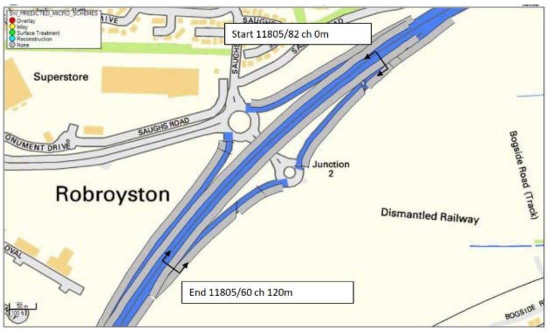
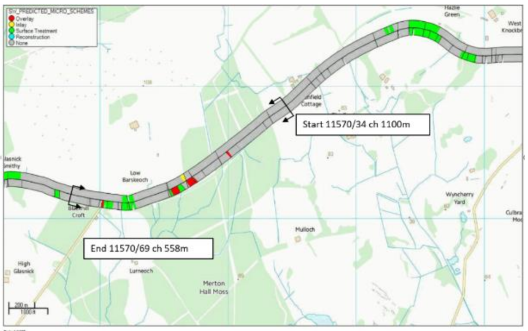
| 17 | 19/SW/0103/015 | <br>• Walk-over, check current status<br>• Footway available for length of scheme | A737 - adjacent to Beith<br>Road Type: S2; length 868m; completed in July 2019.<br><br>Scheme supplied by the OC, noting that they had identified a defect at chainage 286 on CL1 in November 2019. There is a possibility that the defect at chainage 780 is outside the scheme extents. There is no obvious reason for the occurrence of these defects, however it is noted that several treatment depths were reduced from 200mm to 100mm during the review process. There has also been 2 further defects identified (both potholes, at ch.137 & 283). |
| 22 | 19/SW/0103/010 | <br>• Drive over to check status.<br>• Street View (Oct 2020) shows pothole on bridge deck and defect (small pothole) in vicintity of traffic loop. | M80 (SB) - North of Glasgow, nr. Stepps.<br>Road Type: D2H; length 832m; completed in September 2018.<br><br>Eight defects found within the extents, although 2 of the defects described as NB, so may be outside the scheme. The OC had originally proposed a 150mm inlay to CL1, based on the defects present in the VCS and core report, which showed top-down cracking and debonding at 125mm – 145mm in depth. This depth of treatment was questioned during the review process as the crack depths were generally limited to 45mm. The OC conceded that the cracking did not propagate to the proposed treatment depth, but highlighted de-bonding at the binder/base interface. TS questioned whether this treatment would give VfM, and the treatment was reduced to a 50mm inlay only. |
| *21** | 18/SW/0103/002 | <br>• *Not surveyed owing to Covid restrictions. | A75 - Kirkcowan and Newton Stewart Rd.<br>Road type: D2; 1530 m; completed in March 2018.<br><br>This scheme consisted of targeted inlays to the most deteriorated areas. The review from TS remarked that this was an appropriate solution given the pavements variable condition. Eight of the 11 defects previously identified were found to be outside the resurfaced section. The remaining 3 defects (all fretting) are just within the extents giving the possibility that there are no early life defects within this scheme. |

## B.2 SE Survey Sites

| Site no. | Scheme ref | Location/ Survey action | Description/scheme design notes |
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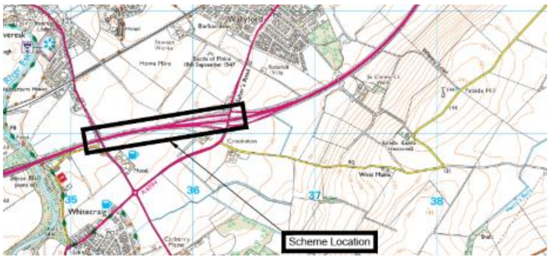
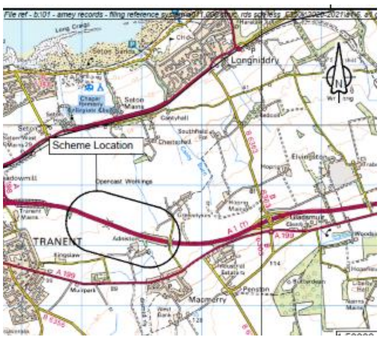
| 14 | 19/SE/0103/025 | <br>• Drive over to check there are no defects<br>• Appears to be a referencing issue with defects.<br>• Eyeball aggregate size. | A1(SB) - approx. 2.5 miles E of Musselburgh<br>Road Type: D2; length 1280 m; completed in Nov 2018<br><br>The six defects recorded as part of this work do not appear to tie in with the information supplied by the OC. This may simply be reporting errors by the inspection team. Some of the deeper treatments consisted of ½ lane inlays, with some concerns regarding the location of construction joints below the wheel tracks. Original design specified a 14mm TS2010. However, according to the MSD, a 10mm TS2010 surface was laid on site. |
| 12 | 20/SE/0103/23 | <br>• Drive over to check status.<br>• Isolated defects clearly visible on Street View (Sep 2020). | A1 (NB) – nr. Macmerry<br>Road Type: D2; length 1509 m; completed in August 2019.<br><br>One defect/small area identified within the scheme extents. Since the initial search in July 2020, there has been a further defect recorded in November 2020 at chainage 1337 – described as 2 potholing patch repairs of 8m x 1m and 4m x 1m in size. |
| 13 | 18/SE/0103/049 | <br>• Walk-over, check current status<br>• Check to see if deeper constructed section is free of defects. [NB. Approx. Ch 70 to 220m from the northern side of the scheme] | A1 - Nr. Houndwood<br>Road Type: S2; length 1,069 m; completed in April 2018.<br><br>Fifteen defects recorded. An inlay of 25 mm thick, 6 mm TS2010 was carried out. In addition, 150 m length of a deeper 100mm localised inlay of 25mm surface course and 75 mm AC20 was used in CL1 only. The OC had proposed a further 100mm inlay in CR1 over the same section length but this was removed from the design. A report on the failures was compiled by the OC. There have also been another five Cat 1 defects repaired since the initial search in July 2020. |

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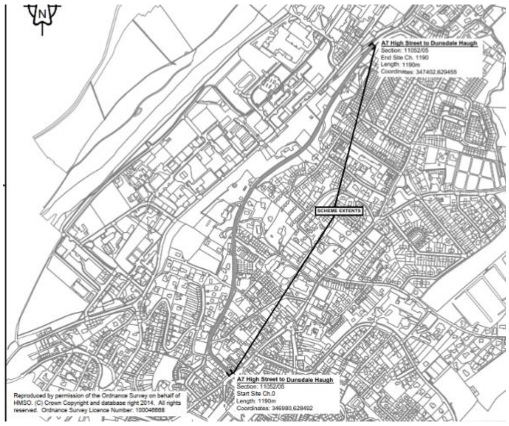
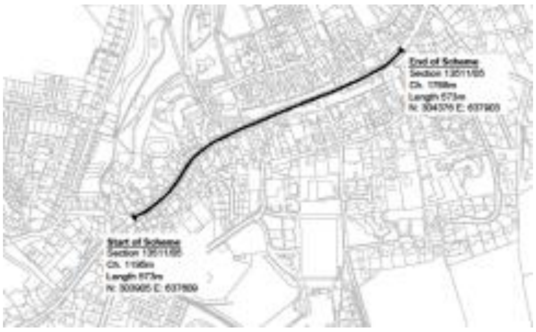
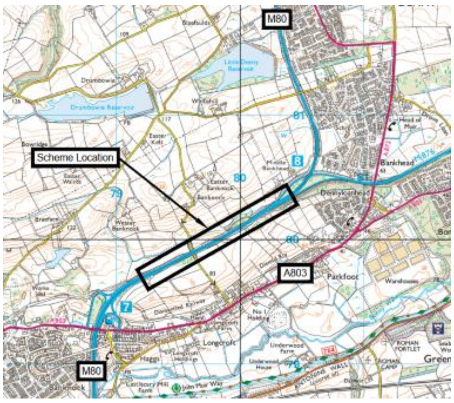
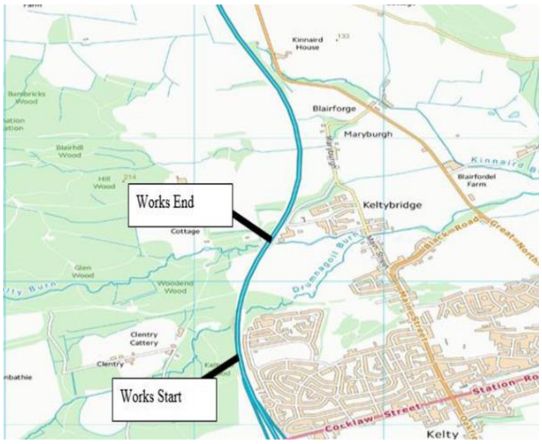
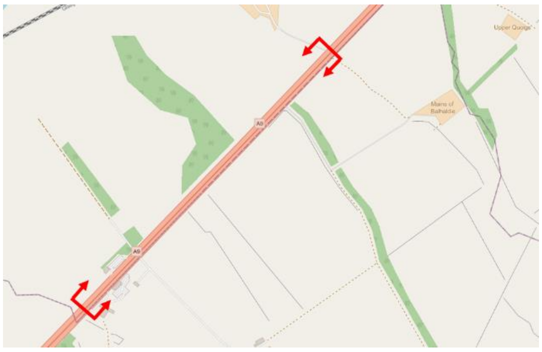
| 15 | 17/SE/0103/020 | <br>• Walk-over, check current status | A7 - Ettrick Terrace, Selkirk<br>Road Type: 2-lane urban single carriageway; length 1,300 m; completed in November 2017.<br><br>Five defects recorded were listed as cracking, patch reinstatements and fretting. TS2010 was initially proposed as the replacement surface course, but during the review process concerns were raised around density of iron work and HRA was used. High levels PAH detected in a significant number of cores which were mostly avoided in the design. The new defects have occurred at locations where previous reinstatements were noted on the VCS and near manholes. Since initial search in July 2020, there has been a further 4 defects recorded. |
| 11 | 19/SE/0103/009 | <br>• Walk-over, check current status | A702 - Broughton Road, Biggar<br>Road Type: 2-lane urban single carriageway; length 663m; completed May 2019.<br><br>Only one Cat 1 pothole identified and repaired in Nov 2019. Additional pothole identified in January 2020. SOI review raised the depth of treatment near failing utility reinstatements. However, the location of both identified potholes does not appear to be in the vicinity of any previous utility trenches although according to the VCS, the most recent defect does appear to be in area that had rutting and reinstatements in the OS wheel track of CL1. |
| 16 | 19/SE/0103/028 | <br>• Drive over to check status.<br>• Faults within bridge deck? | M80 (SB) - between Jct 8 and 7, S of Denny<br>Road Type: 3-lane with H/S;<br>length 1176m; completed in Mar 2019<br><br>Four pothole defects identified within the scheme. Possible that most defects are located on bridge deck – excluded from treatment (825 and 875). Main driver for maintenance was fretting of the existing surface course with potholing. All of the 40 extracted cores seemed to be in good condition with no structural defects. |

## B.3 NE Survey Sites

| Site no. | Scheme ref | Location/ Survey action | Description/Scheme design notes |
|---|---|---|---|
| 1 | 17/NE/0103/031 | <br>• Drive-over, check current status | M90 (NB) - Jct 4 & West of Kelty.<br>Road Type: D2: length 1115 m; completed in November 2016.<br><br>7 defects recorded. The maintenance driver was cracking along the hard shoulder, open joints and fretting. The OC proposed a 120mm inlay including a reinforcement grid in CL1. All of the defects recorded since resurfacing occurred within a 40-metre section of CL1 or the left edge of the C/way. There is a possibility that the fretting defects noted from chainage 128 onwards could be outside the scheme extents and are not early life defects. |
| 3 | 17/NE/0103/015 | <br>• Drive-over, check current status<br>• Starts from job above and finishes just beyond bridge deck. | M90 - Jct 4 to 5 N of Cowdenbeath.<br>Road Type: D2H; length 1,000 m; completed in November 2018<br><br>All four defects happened from chainage 967 to 974, prior to the bridge deck (ch.988-1018). There are some inconsistencies at this location as the MSD indicates that the bridge deck was resurfaced along with the remainder of the site. However, images from Google earth (October 2020) show that perhaps the deck was not resurfaced and that the defect chainage may be inaccurate and the defects occurred on the bridge deck. |
| 5 | 17/NE/0103/016 | <br>• Drive-over, check current status<br>• Closer inspection to be carried out at Layby (one located near beginning of job) | A9 (SB) - NE of Dunblane<br>Road Type: D2; length 1,040 m; completed in April 2017.<br><br>20 defects reported and main maintenance driver was fretting and potholes. The treatment consisted of 40 & 60mm targeted Inlays. Eighteen of the 20 defects since resurfacing occurred within a 51m section of CL1 (Ch 1318 to 1369). Nearest core (1 of 14) to this area (Ch 1381) was recorded as broken to a depth of 95mm. The remaining 13 cores were all in relatively sound condition. |

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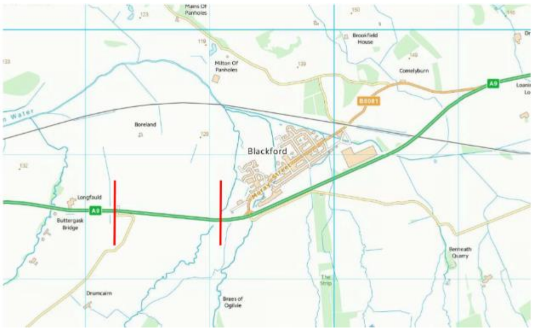
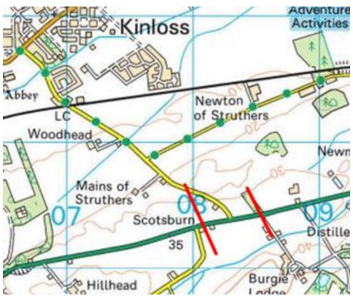
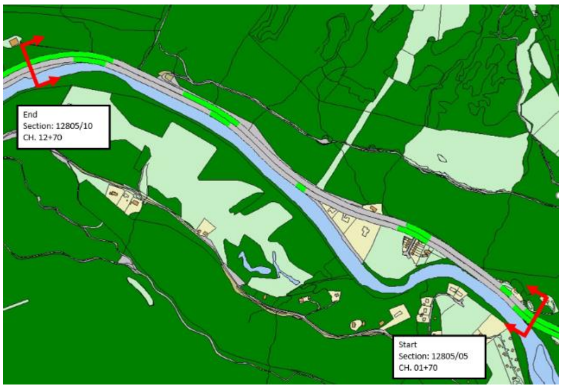
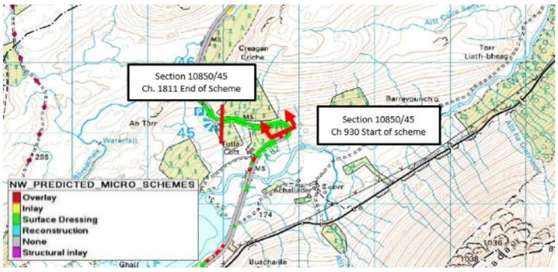
| | | • Is deterioration within shallower inlay? | |
| 6 | 17/NE/0103/018 | <br>• Walk-over, check current status of remedial repairs<br>• Parking at start of job | A9 (NB) - Sherrifsmuir to Blackford<br>Road Type: D2; length 840 m; completed in April 2017.<br><br>10 defects recorded. Maintenance driver for this scheme was fretting. PI found no structural issues. OC had proposed a surface course replacement and not disputed during the review process. All defects recorded since resurfacing occurred on a 17 m section of CL1 (Ch 1520 to 1537). Further core investigation (October 2017) revealed that the binder layer had deteriorated, and was attributed to the presence of clay in binder that broke down during planing operations. A remedial intervention replaced both the surface course and binder course. Street view (2019) show no defects in remedials. |
| *2** | 18/NE/0103/004 | <br>• *Not inspected owing to Covid restrictions.<br>• Street View (Nov 2020) shows repairs to road edge that are not though to relate to reinstatement, i.e. damage due to vehicle over-run. | A95 - Ballindalloch<br>Road Type: S2; length 1375 m; completed in July 2018.<br><br>8 defects recorded. Maintenance driver was to include repair of longitudinal reinstatement. Images from VCS (2017) show cracking, crazing and rutting in the vicinity of this reinstatement.<br>The 8 defects recorded since resurfacing occurred within two 16 m sections (Ch 636 to 652) and 100 m section from (Ch 965 to 1065). If the chainage of the defects is accurate then there is the possibility that they have happened where the treatment depth was limited to 45mm of TS2010. There is also a possibility that the Gas line restricted the pavement investigation, although this is not mentioned in the SOI or review process. There has also been a further 11 defects recorded at this location since the initial search in July 2020. NB Initial SoI states section of A95 is an evolved road with limited drainage. |
| *4** | 19/NE/0103/046 | <br>• *Not surveyed owing to Covid restrictions. | A96 - Forres to Elgin, adjacent to the Kinloss military base junction.<br>Road Type: S2; length 248 m; completed in September 2019.<br><br>2 defects recorded. Treatment consisted of 150mm, with the exception of the turning lane, that received a 45mm Inlay of TS2010. Two areas of fretting reported in March 20. |

## B.4 NW Survey Sites

| Site no. | Scheme ref | Location/ Survey action | Description/Scheme design notes |
|---|---|---|---|
| 7 | 18/NW/0102/006 | <br>• Footway available for part of the scheme. | A887 - west of Invermoriston<br>Road Type: S2; 1732 m; completed May 2018.<br><br>37 defects recorded. The MSD form details show that a combination of 6mm Cl942 and 0/10 mm TS2010 was laid at the site. The 6mm Cl942 from ch.0-194 was implemented in February 2018 while the remainder of the site was resurfaced with TS2010 (10mm) in May 2018. There is no obvious reason for the fretting defects found on this site |
| 8 | 18/NW/0103/095 | <br>• Not surveyed owing to Covid restrictions.<br>• Drive-over, check current status closer inspection to be carried out from side roads | A82 - south of Spean Bridge<br>Road Type: S2; length 1,457 m; completed in September 2018.<br><br>2 defects recorded. The treatment consisted of a 150 mm inlay: 50mm AC20 Dense Binder course was laid on planed surface followed by a pavement reinforcement geogrid with a further 60 mm of AC20 Dense Binder course and a 40mm Cl942 10m surfacing. From the SOI review process, this treatment was devised to address a deteriorated composite pavement construction. The VCS indicated the presence of transverse cracking, edge cracking, potholes, fretting and crazing. The TS review noted that edge cracking might be a result of a different construction at the edges. |
| 11 | 16/NW/0103/038 | <br>• Park at Loch Tulla viewpoint & walk down<br>• Visited during SIP19 (edge defects?) | A82 - North of Bridge of Orchy<br>Road Type: S2; 881m; completed in May 2017.<br><br>5 defects recorded. The OC had originally proposed an inlay consisting of 80 mm binder and 40mm Cl942. Altered during the review process to an overlay due to concerns about the lower layers and leaving them in place. All 10 cores showed disintegration or were broken in the lower layers. Design was changed to an inlay/overlay 70; planing depth of 50mm and overlaying 80mm AC20 and 40mm Cl942 (10mm). There were 5 defects found within the extents, one of the defects was described as "Failed resurfacing" by the inspector. |

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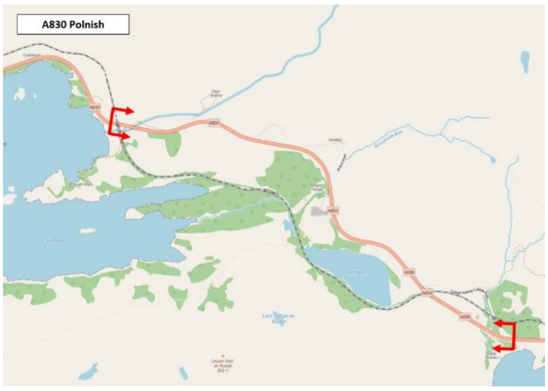
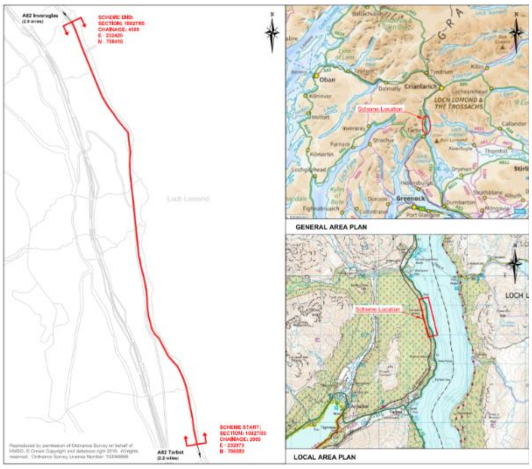
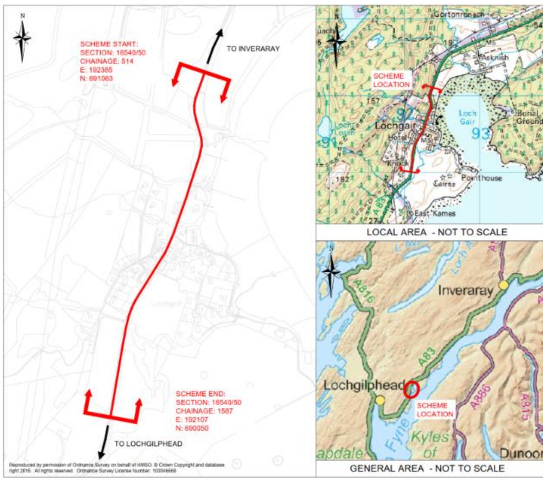
| 10 | 16/NW/0103/044 | <br>• Drive over to check current status<br>• Various side road for closer inspection. | A830 T- Loch Beag to Loch Ailort<br>Road Type: S2; 3,280 m; completed in August 2016.<br><br>40 defects recorded. The treatment consisted of a mix of 40mm and 100mm targeted patches over a 3km stretch of the A830. Defects listed include cracking, fretting and potholes, although due to the nature of the scheme and allowing for discrepancies in defect position reporting, there is some difficulty in determining the exact number of defects - 40 originally identified, reduced to 25 after further review. There were no issues noted during the review process. |
| *9* | 17/NW/0103/133 | <br>• Drive over to check current status | A82 - Tarbet and Inveruglas<br>Road Type: S2; length 1,635 m; completed in September 2018.<br><br>60 defects recorded. Treatment consisted of 40 6 mm Cl942 & 70mm of AC20 Binder. There is limited scope to make any conclusions on this section: missing several documents, including the TS review, VCS and Core report. However, using the MSD construction information and IRIS chainage locations of the defects, it can be seen that 49 of the 60 defects have occurred out with the sections that received a deeper treatment. It was also noted on the SOI that drainage had historically been an issue at this location. |
| *12** | 16/NW/0103/003 | <br>• *Not surveyed owing to Covid restrictions. | A83 - Lochgair / Loch Fyne.<br>Road Type: urban S2; length 1,073m; completed in January 2017.<br><br>16 defects recorded. The initial treatment proposed by the OC was 60mm of EME2 Binder and 40mm of 14 mm Cl942. The design was amended during the review process with the client proposing a 10mm Cl942 and AC20 Binder due to compaction concerns regarding EME2. The defects found as part of the Early Life Failure investigations include edge cracking, fretting, depressions and potholes. There is no obvious reason for the fretting defects found on this site |

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