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## Forensic Examination of Critical Special Geotechnical Measures: Gravity Block Wall Information Note

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# Executive Summary

The effective design, specification and construction of Special Geotechnical Measures (SGMs) is critical to the efficient operation of the National Highways Strategic Road Network (SRN). Given the required performance of the SRN in terms of resilience, reliability, redundancy and recovery it is essential that SGMs are themselves reliable in terms of performance and life; resilient to external conditions such as earthworks deterioration and extraordinary conditions (e.g. climate change). Around 100 different types of SGMs are used on the SRN and the early installations of some SGMs are approaching the end of their design life and the design, specification and application of many of these techniques is based on limited studies.

This Information Note on Block Walls is part of a series that reports on investigations of specific SGMs and makes recommendations on their future use. A detailed account of issues identified on the Strategic Road Network (SRN) is given resulting from the inspection of 10 Block Walls of various types and in various settings. Details of site inspections undertaken by the authors are given in the project final report (Duffy-Turner et al., 2022).

Advice is given on the design, construction, inspection, maintenance and decommissioning of such structures and a series of recommendations is given.

There is no compelling evidence that when properly designed, specified, constructed and maintained, including an appropriate inspection regime, Block Walls cannot meet the required design life of such SGMs.

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# 1 Introduction

This Information Note on Block Walls is part of a wider study of the performance of critical Special Geotechnical Measures (SGMs) (Duffy-Turner et al., 2022) and is one of a series that reports on investigations of specific SGMs, in this case Block Walls with a retaining function, and makes recommendations on their future use.

Block Walls (BLCW), defined as *precast concrete modular block gravity walls* (Figure 1), may or may not be combined with tie-back systems to form reinforced soil walls; the tie-back systems may be formed of either polymeric or metallic mesh. For the purposes of the current exercise only gravity Block Walls (i.e. those without tie-back) have been considered. While the definition of BLCW is quite precise (Atkins/Jacobs, 2020), it is clear that within National Highways' Geotechnical and Drainage Management System (GDMS) the BLCW has been used for other types of walls, namely:

- Masonry Walls (BKRW, defined as *Masonry retaining walls, not including dry stone walls*), and
- Stone Walls (STNW, defined as *Stone-built retaining walls including dry stone walls*).

This may be as a result of an update to the SGM classes that included the above (BKRW and STNW) codes as new types of SGMs. In this Information Note all types, without tie-back, are addressed with differences of approach highlighted as necessary.


**Figure 1: Modular Block Wall on M23 J9 (©AVIS)**

Typically, Block Walls are used on the Strategic Road Network (SRN) as low-height walls around features such as telecommunication housings and at the base of embankments. However, drystone and mortared stone walls are also prevalent on the network in both free-standing and retaining form. In addition, while Figure 1 shows a motorway setting, such walls are very frequently located adjacent to single-carriageway trunk roads including in close proximity to non-motorised traffic.

Block Walls appear in a variety of forms on the Strategic Road Network (SRN) and with a variety of purposes. They may be either dry stone, mortared or comprise proprietary blocks that rely on mechanical interlock and/or friction (e.g. Redi-Rock, Legato and others) to maintain stability between the blocks. Only retaining walls are considered to be SGMs and free-standing walls are covered herein only where they form the upper part of retaining walls.

In all cases, adequate drainage is essential in order to prevent the build-up of water pressure behind the walls which can lead to instability.

Smith (1999) provides a valuable resource, particularly in terms of the geology of building stone and the assessment, use and repair of stone walls. It should, however, be noted that that text focusses primarily on stone for use in buildings where, for example, the repair or replacement of individual blocks is often part of the maintenance regime, but which generally would not be appropriate for Block Walls adjacent to a highway.

For design and construction the requirements for the competence of responsible persons is well-established. However, for inspection such competence is less well-established, and this is considered in Section 5.

## 2 Issues Identified on the Network

A series of site inspections of Block Walls was conducted during October 2020 and January 2021 to establish the prevalence, nature, condition and setting of Block Walls on the Network. During these site inspections a number of issues regarding Block Walls were identified.

Deterioration of the upper courses was observed as was similar deterioration of the lower courses. The top course deterioration appears to be a result of surface water and/or direct precipitation and vegetation and, in most instances, this was accompanied by a loss of mortar (where present) (Figure 2). Deterioration of the lower courses could be caused by a build up of groundwater behind the wall and/or salt spray affecting the roadside face (Figure 3).

**Figure 2: Deterioration and mortar loss of the top course of a stone block mortared retaining wall (A628, SGM 8885 [unique SGM code from Atkins/Jacobs, 2020], October 2020)**

Whether mortar or dry stone, Block Walls have the potential to fail catastrophically, and blocks can become detached and fall to the ground surface (a wall with missing block is illustrated in Figure 3). Similarly, such walls can be vulnerable to vehicle impact (Figure 4). These have the potential to directly cause injury by blocks landing on people from height (Figure 4), or indirectly by fallen debris blocking, for example, footpaths with the potential to cause the public to enter the highway in order to pass.

Cracking of blocks and mortar (Figure 5), bulging and leaning (Figures 6 and 7) were all observed during the site inspections. Sagging and hogging of a modular concrete block (mortar free) ‘Porcupine’-type wall can also be observed in Figure 8.

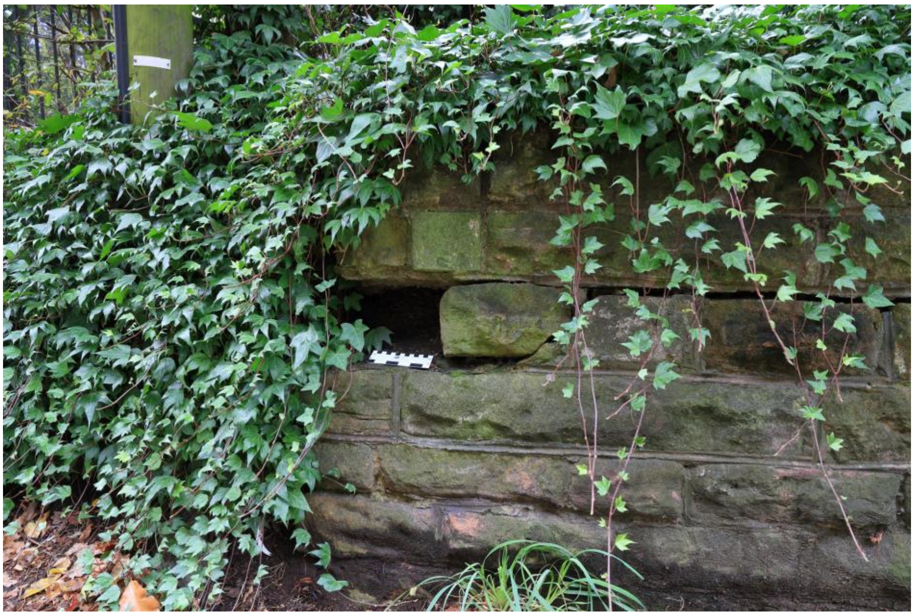

**Figure 3: Deterioration of the lower courses of a stone block mortared wall seems most likely due to salt spray. The deterioration of this wall at this location is through the full height with the loss of block(s) in the central area (A52, SGM 9676, October 2020)**

**Figure 4: Upper free-standing part of a dry stone retaining wall (mortared coping) showing the effects of vehicle impact. The wall below the carriageway retains a height of between 2m and 3m below the road. (A628, east of SGM 8885, October 2020)**

**Figure 5: Cracking of stone block mortared wall (A52, SGM 9676, October 2020)**

**Figure 6: Bulging and leaning of a concrete block mortared retaining wall approximately 0.9m high along base of embankment (A52, SGM 7825, October 2020)**

During the site inspections it was found that the provision of weepholes to Block Walls was relatively uncommon. Figure 9 illustrates an example in which there are no weepholes and seepage through the wall can be observed indicating a likely lack of adequate drainage behind the wall. Notable instances in which weepholes were visible are shown in Figures 10 and 11. In addition, no instances of a vertical drainage layer behind the wall being used were noted, although this can be difficult to identify and confirm without significant and invasive excavation. Where weepholes were observed these generally appeared to be working although in Figure 10 the washout of gravel particles may indicate that construction materials are also being washed out, indicating that there may not be a suitable filter / separator in the construction of the wall/drainage. The lack of adequate drainage is a factor that may cause deterioration and subsequent failure and is an area of potential concern that ought to trigger further evaluation of the Block Wall. It does not necessarily indicate that the risk associated with that failure merits intervention which should be dealt with on a case-by-case basis.

**Figure 7: Leaning stone block mortared wall of approximate height 1.65m. Signs are also evident of bulging and deterioration (including mortar loss) of the top course. Note the change in angle of the masonry courses, the angle between the courses and the coping stones and the vertical alignment of the highway (A628, SGM 8885, October 2020)**

**Figure 8:'Porcupine' modular concrete block wall showing signs of hogging, sagging and bulging. The wall is located in the middle of a slope showing significant signs of instability (A1307 (formerly A14), above SGM 6082 (Gabion wall), October 2020)**

**Figure 9: Mortared concrete block retaining wall, approximately 0.9m high along base of embankment showing signs of bulging, leaning and deterioration of top course (A52, SGM 7825, October 2020)**

**Figure 10: Weepholes (80mm internal diameter at 6m centres) in a 789m long, 0.75m high stone block mortared wall. The gravel particles in front of the wall appear to have been washed out of the weepholes indicating that they are functional but possibly washing out material that forms part of the construction (A30, SGM 1306, January 2021)**

Significant evidence of what appears to be efflorescence was observed at one site (Figures 11 and 12). Efflorescence is formed by soluble salts being drawn out of blocks and concrete by the effects of water including, for example, condensation, rain, snow, dew, spray and the drainage of water through the wall. Efflorescence in and of itself is not generally an indicator of long-term durability issues it can be unsightly. While such aesthetic concerns are unlikely to be an issue on most of the SRN there may be some areas where it does create aesthetic concerns, in particular alongside footpaths where many observed Block Walls are located. Preventative measures may need to be considered if Block Walls are planned to be constructed in visually sensitive areas. Cleaning existing Block Walls exhibiting efflorescence in such locations may be periodically required for maintenance purposes.

Notwithstanding the foregoing, efflorescence may lead to osmotic effects causing water to migrate towards salts to reduce its concentration creating potentially large hydrostatic pressures within the block and subsequent spalling.

**Figure 11: Weepholes (50mm internal diameter) in a 57m long, 1m high concrete block wall. The weepholes were observed to be functional, and what appears to be efflorescence was observed in the blocks and mortar (A38, SGM 10857, January 2021)**


**Figure 12: Concrete block wall showing what appears to be efflorescence in the blocks and particularly in the mortar (A38, SGM 10857, January 2021)**

Changes to the spatial relationship between walls and the infrastructure can also occur when, to a greater or lesser extent, the asset has been developed around the older walls. This can lead to less than ideal configurations. This is an issue that is particularly recognised for dry stone walls (O'Reilly & Perry, 2009) but was found to be more widely applicable.

The wall illustrated in Figure 7 is a good example of this wider applicability; while it is far from clear what the sequence of events may have been, it does appear that the lower part of the wall has been buried and the upper part of the wall (which may originally have been free-standing rather than having to perform as a retaining wall) has been removed. The burial of the lower part of the wall may explain the lack of weepholes on the carriageway side (weepholes were present on the side return of the wall).

Block Walls often form the boundary to third party properties and there can be doubt as to the ownership of the walls. Such walls are commonly observed to have undergone a change in function. At least one example of a block wall was observed during site inspections that appears to be owned by a third party and appears to have been converted from a free-standing block wall to a low height retaining wall (Figures 3, 5 and 13).

Notwithstanding the issues outlined above, dry stone walls in particular can be a relatively resilient form of structure and Figure 14 shows such a wall that has resisted the effects of a small landslide which has overtopped the wall.

**Figure 13: Mortared stone block wall up to 1.7m high showing signs of leaning, block and mortar loss. Brick infills seem to coincide with former driveways; where the block wall is now retaining this may not have been the case originally (A52, SGM 9676, October 2020)**

**Figure 14: Dry stone retaining wall approximately 1.2m height that has been affected by the failure of the slope above (off network, West Yorkshire, August 2012)**

# 3 Design

## 3.1 Standards

In this context, Block Walls include modular precast walls also known as 'dry-stack masonry' walls; dry stone walls; and mortared stone, brick or concrete block walls. Typically, these are designed as gravity retaining walls, but may also contain an upper portion that is free-standing (e.g. Figure 4). Some older walls may have originally been constructed as free-standing (e.g. Figure 13) and have changed use (are now performing a retaining function), over the course of their lifetime. Free-standing walls are not always specifically discussed in many of the guidance documents. Table 1 summarises the range of information provided for design, specification and construction of Block Walls.

**Table 1: Matrix of relevant documentation available for Block Walls**

**Level of information provided:** Background, Marginal, Comprehensive

**Relevant to:**

| Publisher | Document number and title | Design BLCW | Specification BLCW | Construction BLCW |
|---|---|---|---|---|
| BSI | BS 8002:2015 Code of practice for earth retaining structures | | | |
| BSI | BS EN 1997-1:2004+A1:2013a Eurocode 7: Geotechnical design - Part 1: General rules | | | |
| CIRIA | CIRIA (O'Reilly & Perry, 2009) RP723 Dry stone retaining walls and their modifications – condition appraisal and remedial treatment | | | |
| CIRIA | CIRIA (Chapman et al., 2000) C516 Modular gravity retaining walls, design guidance | | | |
| CIRIA | CIRIA (Perry et al., 2003a) C591 Infrastructure cuttings - condition appraisal and remedial treatment | | | |
| CIRIA | CIRIA (Perry et al., 2003b) C592 Infrastructure embankments - condition appraisal and remedial treatment | | | |
| ICE | ICE (Burland et al., 2012) Manual of geotechnical engineering | | | |

Specification and construction guidance is not particularly comprehensive for Block Walls. In many cases, the use of a particular manufacturer's product would likely mean the manufacturer would be approached directly for guidance.

The most comprehensive source of design guidance for gravity retaining walls is the British Standard BS 8002, the Code of Practice for earth retaining structures. Other documentation specifically mentions 'dry-stack masonry' walls, and refers to the design methodologies for gravity walls, for instance CIRIA C516 (Chapman et al., 2000) and Burland et al. (2012).

Some walls adjacent to the SRN date back, at least, to the early-twentieth Century and in some cases may be even older. The age of many such walls means that their construction may or may not have been subject to formal design and where they were designed, the associated records are much less likely to be available. Unsurprisingly they often appear on older parts of the network where the interface between the asset and road users may not meet current construction standards. In such circumstances there will be doubts over what constitutes an appropriate approach to assessing, maintaining and intervening with such walls.

Such walls may have been subject to significant change during their service life including, but not limited to, loading; spatial relationship with the infrastructure; transition from free-standing to retaining (either partially or wholly); and deterioration of the wall and its components. As repairs have been effected and changes made to the asset, the form of Block Walls may have also changed along with, potentially their function, all of which have the potential to increase the likelihood of failure.

Where blocks are manufactured, any design guidance offered by the manufacturer should be considered alongside sound design principles intended to ensure the stability of the wall against sliding, toppling/overturning, bearing, internal failure and any other relevant modes of failure. An assessment of ground aggressivity is required to ensure that the blocks and other components are resistant to such conditions as well as to the potential effects of the road environment, including those of de-icing products.

## 3.2 Layout

Typically block walls will be laid out with a stretcher bond pattern to maximise internal stability. While this may not be possible for dry stone walls, and some mortared stone walls, depending on the variation in size and shape of the blocks used, the general principal that vertical joints should not coincide over more than two courses is generally recommended in most guides (e.g. Haramy et al., 2006).

## 3.3 Materials

The blocks themselves may be formed from concrete, brick or stone, and the blocks may be mortared or be stacked mortar free. Many manufactured blocks include some sort of mechanical interlock between adjacent (vertical and/or horizontal) blocks.

A modular concrete block ‘porcupine’ wall (mortar free) is illustrated in Figure 8, while a mortared concrete block wall is shown in Figure 9.

A mortared stone block wall and a dry stone wall are illustrated in Figures 13 and 15 respectively, the latter of which also illustrates a brick mortared wall.

## 3.4 Drainage

Effective drainage is essential to the long-term stability of Block Walls, whatever their form. It can be provided by weepholes in combination with drainage to the rear face of the wall but can be provisioned such that the rear face drainage allows water to flow laterally to a suitable outlet. The provision of a filter is essential to prevent the transmission of fines into the vertical drainage layer, with loss of material behind the wall and associated silting up of the drainage layer/system.

**Figure 15: Dry stone wall approximately 2.5m high including 0.5m free-standing (A628, SGM 8923, October 2020)**

## 3.5 Environmental Considerations

Many of the relevant environmental considerations for Block Walls, both with and without mortar, are similar to those identified for dry stone wall construction and behaviour in CD 459 (*The assessment of bridge substructures, retaining structures and buried structures*) as discussed in the paragraphs below.

Dry stone, and other older walls, were often constructed without recognisable foundations and may have been constructed with materials that range from high quality dressed local stone to material of marginal quality. Many stone retaining walls may have only the front face formed from dressed masonry, the material to the rear of the face usually being rubble. This is particularly likely to be the case in parts of England where weak sandstones and limestones predominate, and competent material may have been in short supply. Argillaceous rocks should not be used to construct Block Walls of any type on the SRN. Other stone retaining and free-standing walls, will have competent stone faces on both sides (e.g. Mundel et al., 2010).

Percolation of ground water and waterborne salts through the fabric of the wall can result in weathering and the leaching of fines from within the structure.

Salt spray resulting from de-icing salts may cause deterioration in the fabric of the lower parts of the wall.

Weathering can occur more in some areas of the wall than in others due to the very variable quality of the masonry used.

Random weathering and unsatisfactory foundations may result in differential settlements, movements and bulging which induces acute stresses in some elements of the structure causing cracking of the stones and/or mortar causing either or both to become loose and subsequently dislodged.

Additional considerations for mortared walls include that the percolation of water into the top one or two courses may cause premature deterioration of the mortar and subsequent loss. Such walls are also much stiffer than walls without mortar and less able to accommodate movement without obvious cracking and mortar and/or block damage or loss.

Additional considerations for dry stone or block walls without mortar include that the absence of mortar may result in stone-to-stone contact, and since the stones used in the walls are usually irregular or roughly squared off, point contact between stones is common. Contact pressures may be high, especially at the base of tall stones within the wall, and crushing is often evident.

Dry stone walls can move and distort until sufficient interlock strength has been gained between stones. This can give an irregular profile albeit that the wall can still provide satisfactory in-service performance.

The open nature of a dry stone wall permits weathering of the face and inside the open joints, reducing the area of contact and encouraging further crushing.

## 3.6 Technical Approval

Key considerations for the design and specification process include the following:

- Is a block wall of the type proposed best suited for the application and environment?
- Has the design considered the block wall in relation to sliding, overturning, bearing capacity, external stability and internal failure?
- If a specific manufacture-type block wall is proposed has a BBA certified product been obtained for the system, and if not, why not? Have all manufacturer recommendations been reviewed and translated into the design and construction specification as appropriate?
- If stone blocks are be used is the stone clean, hard and durable and of such quality that it will not deteriorate or fragment due to exposure to water or weathering during the design life of the wall?

The structures approval process is set out in CG 300 and is applicable to Block Walls. Typically the scheme designer is expected to discuss and agree the appropriate structural category with the SES Structures Advisor in advance of the design process.

CD 622 shall be applied to the geotechnical aspects of Block Walls.

# 4 Construction

## 4.1 Materials

It is important that all blocks (brick, stone, concrete, etc.) and mortar used in Block Walls has the potential to maintain its integrity in the light of the mechanical and environmental stresses that it might face during its design life. These can include contact stresses in the case of dry stone walls and the effects of de-icing salts for all forms of wall.

High contact stresses can be caused by incorrect handling during transport and construction such that concentrated loads are generated rather than the blocks being placed square on top of each other, or by subsequent movement of the retained material or deterioration of the block(s).

## 4.2 Drainage

Effective drainage is a requirement for all Block Walls, including dry stone walls. This may be achieved by means of weepholes connected to a vertical drainage layer behind the wall or the vertical layer can be used to effect horizontal water flow to a suitable outlet.

The core and/or vertical drainage layer of dry stone walls are usually formed from the naps from stones used for face(s) and/or readily available local material; both should be free draining. Caution is required if some less durable materials are to be used (including some mudstones, siltstones and fine sandstones) that may deteriorate and inhibit the free passage of water. The source geology of such materials is thus a significant consideration in the design, construction, inspection and maintenance of such walls.

## 4.3 Supervision and Construction Quality Assurance

Adequate and competent personnel for construction and supervision should be provided to ensure that construction follows both the design requirements and the requirements of the MCHW.

Construction quality assurance records shall be kept and provided to the Overseeing Organisation throughout the construction process and for SGMs the records of the auditing process should be captured in the Geotechnical Feedback Report (GFR).

## 4.4 Construction Acceptance

Contractor self-certification of SGMs should not be accepted. Observations on the SRN and of the wider UK infrastructure portfolio have found the self-certification process to be suboptimal.

It is important that snagging is undertaken (and completed) prior to the contractor leaving the site and that the Overseeing Organisation’s representative is afforded adequate opportunity to formally accept the work undertaken prior to the contractor leaving the site. In many instances these activities will need to be planned and executed prior to removing traffic management.

Acceptance once site access is restricted (i.e. once the road is fully-operational) is frequently not an option as access without Traffic Management at best limited and at worse unsafe. It is recommended that provision for early inspection be built into the contract along with the potential consequential non-payment of all or part of the contractor’s final invoice.

# 5 Inspection

Block Walls shall be inspected and maintained in accordance with the DMRB, particularly CG 302 *As-built, operational and maintenance records for highway structures*, CS 450 *Inspection of highway structures* and CS 459 *The assessment of bridge substructures*, retaining structures *and buried structures* and CS 641 *Managing the maintenance of highway geotechnical assets*.

Specific maintenance or ongoing monitoring requirements for the Block Wall shall be highlighted in the Geotechnical Feedback Report produced by the DGA within six months of the end of the construction phase.

## 5.1 Frequency

The frequency of inspections should be based on assessment of the risk posed to the network, third party assets, users, workers or others by deterioration of the assets as set out in the relevant DMRB documents. Typically the higher the risk, the greater the appropriate frequency of inspection. Notwithstanding this, O'Reilly & Perry (2009) noted that inspections of dry stone walls, in particular, should be carried out regularly as once deterioration commences this can lead rapidly to the collapse of sections of wall. This recommendation reflects the fact that dry stone walls are generally considered to be higher risk and that this should influence the frequency of inspection.

## 5.2 Detail

Visual assessments will, in almost all cases, be the most likely mode of inspection and will require the application of sound engineering judgement and CS 459 gives good advice in respect of dry stone walls and most of this is equally applicable to mortared stone walls and indeed mortared and mortar free concrete block walls. The advice given in CS 459 is adapted and expanded below based on observations made during inspections on the network and to be applicable to all Block Walls:

1. Block Walls shall be assessed qualitatively. It is noted that quantitative, and even qualitative, judgements are difficult since conditions will vary greatly with the quality of stone used, age, subsoil conditions, drainage, geometry, weathering factors and local expectations.
2. The assessment of Block Walls should be based upon the results of visual inspections and surveys.
3. The inspection for assessment of Block Walls shall include the identification of the following:
   a) the type, size and shape of blocks and/or stones;
   b) the condition of mortar (where present);
   c) the age of the wall;
   d) the skill with which the stones have been laid or replaced;
   e) signs of bulging, leaning, hogging, sagging or other loss of profile;
   f) cracking of mortar (where present) and/or of individual blocks;
   g) stone loss, particularly from the upper and/or lower courses of the wall;
   h) mortar loss (where present), particularly from the upper and/or lower courses of the wall;

i) the provision or otherwise of drainage and the effectiveness of drainage where present;
j) the likely nature of the retained material (if any) and that supporting the wall foundations;
k) the existing loads carried by the wall(s) in terms of traffic volume;
l) environmental stresses such as the likelihood and/or visible effects of de-icing salts;
m) the presence (in and around the wall) of vegetation;
n) influence of trees and vegetation on the wall stability; and
o) any likely changes to the function of the wall during its life (e.g. a wall originally constructed as a free-standing wall that is currently retaining for all or part of its height).

4. Assessment of Block Walls shall include a comparison with the performance of any adjacent structures.
5. Local experience of the behaviour and comparison with past performance of the structure should be used to inform the assessment when available.
6. Wall length, height, angle and condition of any retained slope should also be recorded.
7. Block Wall facings to rock slopes must be treated with care. These may or may not be designed as retaining walls. Their assessment should be based upon the current and likely future weathering state and extent of the material behind the wall and whether the development of a fully-active, or near fully-active, wedge is likely.

## 5.3 Competence

It is recommended that the inspection of SGMs should be certified by a Geotechnical Advisor in accordance with CD 622.

# 6 Maintenance

Maintenance (and demolition) of the structure or SGM should be considered throughout the design, specification and construction process, as described in SG 300 and associated plans should be prepared and incorporated into the handover documentation and additionally included in the GFR.

Block Walls, whether mortar or dry stone, have the potential to fail with blocks falling to the ground surface often from the top course (coping) and the potential to cause injury and blockage of, for example, footpaths causing the public to enter the highway in order to pass. Cracking, bulging, leaning and seepage/lack of drainage provision are all indicators of potential failure but do not necessarily indicate that the risk associated with that failure merits intervention. Ownership may also be uncertain.

O'Reilly & Perry (2009) give cost comparisons of various forms of reconstruction and repair techniques for different heights of dry stone walls and also note that the annual costs of maintenance of such walls are around 0.75% of their replacement cost. While the actual costs date back to around 1995 the relative comparisons are considered to remain valid with those of pressure pointing and soil nailing being around 12% and 50% of replacement structures.

Maintenance of dry stone and many stone block mortared walls must be taken in the context of the history and the natural and cultural heritage of their setting. Amongst the walls inspected during the site visits was a wall retaining an ancient cemetery within the Peak District National Park. It should be clear that a degree of sensitivity and consultation will be required prior to any major maintenance works and that this will be particularly so if any intrusive repair (e.g. soil nail repair) or reconstruction is considered.

## 6.1 Ownership

If there is doubt as to the ownership of wall(s) on the SRN, the first step should be to interrogate National Highways Integrated Asset Management Information System (IAMIS) and the 'Lands' layer/application in the National Highways GIS (HAGIS). If this confirms that the land is not owned by National Highways or is inconclusive then advice should be sought from Land Enquiries (LandEnquiries@highwaysengland.co.uk). Such a referral should not limit or delay works required for the purposes of ensuring the safety of workers, road users or the public, or for ensuring the continued viability of the asset. The power to take such action is conferred through the Highways Act 1980 (Clauses 165 and 167) on the Highway Authority, although it is recognised that such powers are generally used only after taking cogent and relevant legal advice.

## 6.2 Assessment

In the context set-out above, a risk-based approach to decision-making, in particular the determination of maintenance and potential intervention on Block Walls, seems to be indicated. This should consider the following aspects:

- Likely impact of failure on the asset (road and/or earthwork).
- Likely impact of failure risk to public (motorised and, if relevant, non-motorised users).

- Whether design and/or construction details are available to undertake a more detailed evaluation.
- Whether the main issues are structural, geotechnical or both, thus determining the nature of the expertise required.
- Whether the wall appears to be fulfilling its original function or a modified function (e.g. free-standing converted to retaining).
- Whether the wall is in its original form (e.g. dry stone converted to mortar, at the face at least).
- Any other site-specific factors (e.g. whether the retained soil forms part of a cultural or religious site).

Formalising this process is a not insubstantial task given the wide range of wall types and settings, and certainly beyond the scope of the present project. However, it is possible to provide examples to illustrate both the logic and the decision-making process and that could assist in the calibration of a more formal risk assessment process.

***Case study 1*:** Mortared concrete block retaining wall, approximately 0.9m high along base of embankment (A52, SGM 7825, Figures 6 and 9). This wall shows signs of cracking, leaning and bulging. However, the complete failure of the wall is likely to cause only minor failure of the embankment but it is considered that this is unlikely to cause immediate damage to the road and/or vehicle restraint system and that it can be managed as and when it occurs.

***Case study 2*:** Mortared stone block wall up to 1.7m high (A52, SGM 1109, Figures 3, 5 and 13,). The wall shows signs of leaning, and block and mortar loss. Brick infills appear to coincide with former driveways and where the block wall is now retaining this may not have been the case originally. It is considered that while there are clear signs that maintenance will be needed in due course the first step should be to ascertain ownership.

***Case study 3*:** Mortared stone block retaining wall up to 1.65m high (A628, SGM 8885, Figures 2 and 7) The wall shows signs of bulging, leaning and deterioration (including mortar loss) of top course as well as potential changes to the asset alignment. The anomalies to the alignment of the courses relative to absolute level and road level are a cause for concern along with the lack of drainage to the roadside wall that retains the local cemetery. Further, potentially intrusive, investigation of this wall is recommended.

***Case study 4*:** 'Porcupine' modular concrete block wall (A14, above SGM 6082 (Gabion wall), Figure 8). This wall shows signs of hogging, sagging and bulging. While in isolation these are not cause for concern, wider observation of the slope on which the wall is situated reveals that the slope is showing significant and long-term signs of movement and that further investigation is necessary (Figure 16).

**Figure 16: Slope above the 'Porcupine' modular concrete Block Walls (Figure 2) showing settlement beneath the foundation for a variable message sign and significant long-term twisting of tree trunks indicating a wider instability issue (A1307 (formerly A14), above SGM 6082 (Gabion wall), October 2020).**

***Case study 5*****:** Concrete block mortared wall where efflorescence is evident in both the blocks and the mortar (A38, SGM 10857, Figures 11 and 12). Efflorescence can be an aesthetic concern in areas accessible to the public and in such cases, cleaning may need to be considered as part of the maintenance regime. The associated osmotic effects can also cause large hydrostatic pressures within block leading to spalling and observations targeted at identifying this phenomenon shadow be part of the inspection regime.

***Case study 6*****:** Stone block mortared wall (A303, SGM 1268, Figures 17 and 18) forms the headwall to a deep drain that subsequently leads to a larger channel (Bearley Brook) that passes under the carriageway. Visual observations indicate that there is substantial mortar loss, sagging and bowing of the wall and that, in places, this has led to substantial misalignment of the individual blocks with the potential for individual blocks, or groups of blocks, to be lost. Failure of the wall would most likely lead to undermining of the foundation of the vehicle restraint system (just visible through the wooden fence in Figure 17). It is recommended that further assessment of the stability of the wall is undertaken. It is also notable that remediation works have been carried out to the wall effectively burying the structure in the area immediately adjacent to the wall pictured in Figures 17 and 18.

**Case study 7:** Dry stone wall (A36, SGM 9077, Figure 19) immediately adjacent to the carriageway exhibits substantial bowing, distortion and block loss as a result of vegetation invasion, landsliding and potentially the action of frost and de-icing damage. It is clear that reconstruction of this wall is a priority and it is understood that this is planned for the near future.

**Figure 17: Stone block mortared wall showing significant signs of instability (A303, SGM 1268, January 2021).**

**Figure 18: Stone block mortared wall showing significant signs of deterioration, as well as gross instability as shown in Figure 17 (A303, SGM 1268, January 2021).**

**Figure 19: Dry stone wall showing significant signs of instability (A36, SGM 9077, January 2021).**

# 7 Decommissioning

Safe decommissioning, or demolition, should be a consideration from the outset (Approval in Principle) as required in CG 300 including the difficulty of taking down high Block Walls and the provision of an alternative form of support to the retained material/structure.

# 8 Recommendations

In the GDMS the different types of walls appear to not always be differentiated and Block walls (BLCW) appears to be the default selection for all walls including Masonry walls (BKRW) and Stone walls (STNW). This may be an instance where SGM categories have become too highly-resolved and it is recommended that consideration be given to combining these categories.

The interface between SGMs and structures is clearly an important issue, and it is not entirely clear which types of Block Wall (material, structure or function) are being recorded in IAMIS. It is recommended that the Structures Manager review the SGM layer in GDMS.

There is no compelling evidence that when properly designed, specified, constructed and maintained, including an appropriate inspection regime, Block Walls cannot meet the required design life (120 years) of such SGMs.

Advice in standards and other related documents for Block Walls is clearly limited. Through the course of this work a number of key issues have been identified and these are set out as recommendations for action in the following paragraphs.

***Recommendation 1:*** The design of Block Walls should take due cognisance of manufacturer's information, where relevant, as well as fundamental design principles.

***Recommendation 2:*** The provision of adequate and appropriate drainage for Block Walls should be addressed through the design, specification and construction phases.

***Recommendation 3:*** The use of argillaceous rock to form Block Walls is not recommended, due to the possibility of rapid deterioration, in particular in locations of high exposure.

***Recommendation 4:*** Contractor acceptance, or self-certification, of Block Walls is not recommended.

***Recommendation 5:*** Any inspections for the acceptance of constructed Block Walls should be undertaken prior to the site becoming fully-operational and it is recommended that provision for early inspection should be built into the contract.

***Recommendation 6:*** Construction quality assurance records for SGMs should be captured in the Geotechnical Feedback Report (GFR).

***Recommendation 7:*** Inspection of SGMs should be certified by a Geotechnical Advisor in accordance with CD 622.

***Recommendation 8:*** It is further recommended that the development of a formal risk-based approach for inspection and maintenance of Block Walls be considered. This would assign values to attributes of Block Walls during assessment to allow prioritisation of actions including maintenance and replacement. Attributes to be considered include but are not limited to, wall type, condition, provision and effectiveness of drainage, proximity to road users. The examples given in Section 5.2, which have been developed in consultation with National Highways Geotechnical Team members, could be used to help calibrate the system.

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# Appendix A Details of the Block Walls Inspected

| SGM Type | SGM ID | Area | Road | Location | Eastings | Northings | Date |
|---|---|---|---|---|---|---|---|
| Block Wall | 9676 | 7 | A52 | Nottingham | 453520 | 338574 | October 2020 |
| Block Wall | 7825 | 7 | A52 | Nottingham | 457786 | 334693 | October 2020 |
| Block Wall | 9407 | 12 | A628 | Crowden | 407373 | 399305 | October 2020 |
| Block Wall | 8923 | 12 | A628 | Tintwistle | 402639 | 397407 | October 2020 |
| Block Wall | 8885 | 12 | A628 | Tintwistle | 402413 | 397305 | October 2020 |
| Block Wall | 1268 | SW | A303 | Ilchester | 351027 | 121606 | January 2021 |
| Block Wall | 1306 | SW | A30 | Monkton | 319613 | 104545 | January 2021 |
| Block Wall | 9077 | SW | A36 | Dundas Aqueduct | 378323 | 162595 | January 2021 |
| Block Wall | 10857 | SW | A38 | Liskeard | 223568 | 64425 | January 2021 |
| Block Wall | 11542 | SW | A36 | Bath | 376593 | 165805 | January 2021 |

# Forensic Examination of Critical Special Geotechnical Measures: Gravity Block Wall Information Note

The effective design, specification and construction of Special Geotechnical Measures (SGMs) is critical to the efficient operation of the National Highways Strategic Road Network (SRN). Given the required performance of the SRN in terms of resilience, reliability, redundancy and recovery it is essential that SGMs are themselves reliable in terms of performance and life; resilient to external conditions such as earthworks deterioration and extraordinary conditions (e.g. climate change). Around 100 different types of SGMs are used on the SRN and the early installations of some SGMs are approaching the end of their design life and the design, specification and application of many of these techniques is based on limited studies. This Information Note on Block Walls is part of a series that reports on investigations of specific SGMs and makes recommendations on their future use.

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