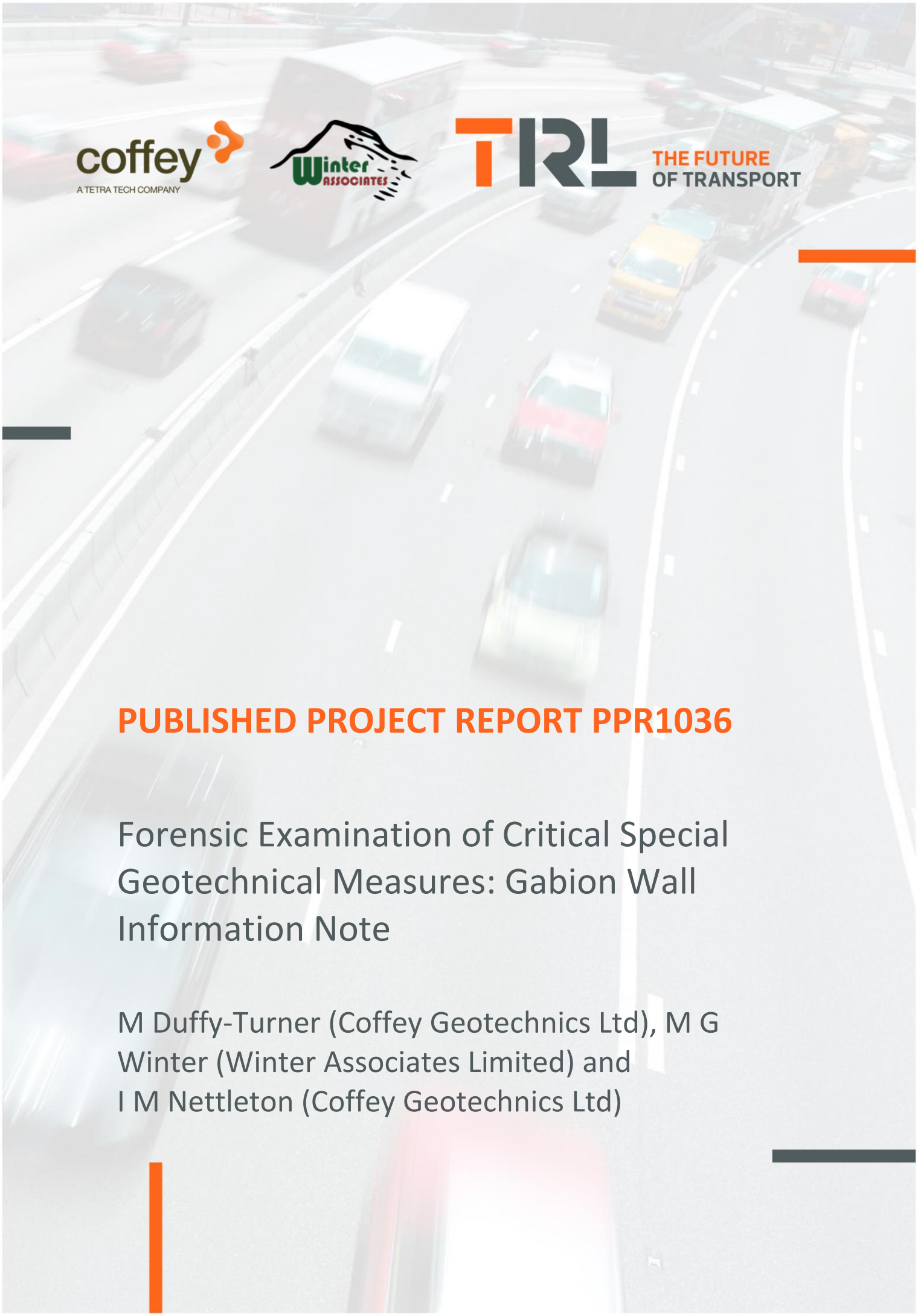

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Forensic Examination of Critical Special Geotechnical Measures: Gabion Wall Information Note

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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 Gabion 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 Gabion Walls 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, Gabion Walls cannot meet the required design life of such SGMs.

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1 Introduction

This Information Note on Gabion 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 Gabion Walls, and makes recommendations on their future use.

Gabion Walls (GABN) are defined as *gabion gravity retaining walls* (Atkins/Jacobs, 2020) and walls formed from gabion baskets form inherently flexible structures (e.g. Figure 1). This can be beneficial in terms of the accommodation of movements without reaching either their serviceability or ultimate limit states. This is, however, demonstrably poorly understood and there are a number of examples in which Gabion Walls have been deemed to have failed despite accommodating movements without distress.

Typically, Gabion Walls are used on the Strategic Road Network (SRN) as relatively low height (generally less than 5m high) retaining walls at the toe of embankments, often to reduce land take. They are often adopted during the construction phase to deal with unforeseen site constraints as they arise. This can lead to rapid decision-making and an apparent lack of design and/or construction control and supervision.

Figure 1: Example of a retaining structure formed from Gabion baskets (from Winter et al., 2009)

Like all Special Geotechnical Measures (SGMs) gabion baskets and walls must be designed and constructed in a manner sympathetic and appropriate to their form and behaviour. This Information Note provides advice for design and construction of Gabion Walls and highlights known issues and pitfalls associated with these. During the original review of the SGMs (Duffy-Turner et al., 2022), discussions were held with National Highways technical staff and the supply chain to determine what issues with Gabions Walls had arisen on the network. The feedback was that gabion walls were often located in critical locations where failure may pose a significant risk to the network and that defects and failures had occurred previously. The major concerns with Gabion Walls were associated with poor design (i.e. founded on peat), incorrectly sized fill materials and construction issues related to packing.

2 Issues Identified on the Network

A series of site inspections of Gabion Walls was conducted during October 2020 and January 2021 to establish the prevalence, nature, condition and setting of Gabion Walls on the SRN. During these site inspections a number of issues regarding Gabion Walls were identified. Thirteen Gabion Walls were inspected with ages ranging from eight to 46 years (see Appendix A). These included seven welded mesh gabion walls; four woven mesh gabion walls; and two strengthened earthworks which were recorded as gabion walls in the SGM dataset (Atkins/Jacobs, 2020) but on inspection were found to be tied back reinforcing mesh.

Two types of gabion baskets were observed on the network: woven gabions and welded mesh gabions. The welded mesh gabions were more prevalent with nine out of 12 identified during the inspections. There were issues identified with both types of gabion basket.

One issue that was observed for welded mesh baskets, but is relevant to both types, is that large voids can be created if filling of the baskets is not undertaken with great care. This can lead to movement of the fill within the basket during the service life putting undue strain on the mesh and the system used to join the panels of the baskets, where additionally the baskets are formed from welded mesh this may cause undue strain on the welded joints. This is a particular issue when non-rectilinear are used to accommodate, for example, curved walls (Figures 2 and 3) and typically such walls are formed using welded mesh backets, but the primary point relates to both basket types and such internal movements, if sufficiently great, could potentially compromise the overall stability of the structure.

Notwithstanding this, the most significant problems were observed in relation to the construction of welded mesh gabions.

All gabions used on the Network should be from a recognised and approved manufacturer and possessing a BBA certificate (or equivalent). These are purpose made gabion baskets in line with the MCHW requirements and should be installed correctly as per the manufacturer's instructions. The issues identified that have arisen on site with these are as follows:

- That the visible faces (front, side and top) of welded mash baskets were often seen to overlap with adjacent baskets with a single piece of mesh forming the panel to more than one basket in whole or in part (Figure 3). Effectively the walls were not comprised of individual baskets but of inconsistently interlinked and overlapped panels; this will render any future repairs and decommissioning both difficult indeed and potentially hazardous.
- Cutting of wires and wear to the corrosion protection may be introduced, both of which may reduce the service life of the wire (Figures 4 and 5).
- The incorrect fastening of baskets compromising the structural integrity of the individual baskets (Figure 6).

Both galvanised and plastic-coated corrosion protection were observed and both good and bad instances were observed of each. The poor examples showed damage (possibly transport, construction, site or general wear) to the corrosion protection (galvanisation and plastic) on some of the welded baskets which could be peeled off using the observer's fingers without difficulty (Figure 7). Corrosion or damage to the corrosion protection was not observed on

any of the woven baskets, albeit that the majority of the baskets inspected were of welded mesh.

Examples of a plastic coating upon galvanisation were observed in some locations (Figure 7). In one case the coating appeared to be brittle and thin and was considered to be unlikely to conform to the requirements in the MCHW.

Clearly the reduction of any potential sacrificial thickness, and ineffective corrosion protection is something of a problem in terms of durability and resilience with both the level of protection offered and the expected life of the wire reduced.

Figure 2: Curved Gabion Wall (A38/A61 Junction, SGM 7630 [unique SGM code from Atkins/Jacobs, 2020], October 2020)

Figure 3: Top view of a curved Gabion Wall showing overlapping front panels (A38/A61 Junction, SGM 7630, October 2020)

Figure 4: Large voids can be left if baskets that are not rectilinear are not filled correctly. The void reaches back for more than 0.5m behind the front facing stone in the left hand basket (A45/A46 Junction, SGM 9117, October 2020)

Figure 5: Plastic coating peeling away at the edges of the gabion basket where the mesh and wires have been cut (A45/A46 Junction, SGM 9117, October 2020)

Figure 6: Top of gabion basket fastened to the adjacent basket compromising the structural integrity of the basket (M60, SGM 5281, October 2020)

Figure 7: Coating peeling away from mesh on welded gabion basket (A453, SGM 4025, October 2020)

A wide range of stone fill materials has been observed from a granite, that clearly conformed to the requirements of MCHW (Figure 7) to a shale (argillaceous) that did not and was showing significant signs of deterioration (Figure 8). Significant deterioration causing settlement of the fill was observed in the latter material. Signs of deterioration in both sandstone and limestone rock fill were also observed, albeit not to a degree so as to raise concerns about the long-term integrity of the fill. Other seemingly unsuitable fill materials observed, that would most likely not meet the MCHW requirements, included chalk and waste-derived concrete, asphalt and brick (e.g. Figure 9).

The fill used in the gabion baskets pictured in Figure 9 is also oversized compared to the allowable limit in the MCHW. This undoubtedly contributed to the overall unsatisfactory condition of the baskets which were observed to be barely containing the fill due to distortion and breakage of both the wire and the fastenings. The embankment slope retained by the gabion wall was observed to be moving which may be attributed to loss of support from the gabion below. At the crest of this slope was a concrete foundation which was becoming undermined by the slope movement below.

One example, for which the maximum size of fill was exceeded (Figure 10) used carefully placed local building stone to provide an attractive finish to the baskets. Although the maximum fill size was exceeded this is generally considered acceptable, provided that a Departure from Standards was granted in advance of the Works.

Other than where carefully placed (e.g. Figure 10), the use of oversized stone was associated with significant voids. Such voids were also associated with undersized material that could be readily removed from the baskets (e.g. Figures 8 and 11).

The environment in which gabion baskets are placed is also important. Significant corrosion was observed in a series of baskets that were placed in a marine environment and the damage

was significant to the extent that in places the loss of fill exceeded 80% rendering the SGM ineffective in fulfilling its support function (Figures 12 and 13).

Figure 8: Shale showing significant signs of deterioration: this material is considered not to meet the MCHW requirements (M60, SGM 7038, October 2020)

Figure 9: Oversize concrete fill leading to large voids within the gabion baskets. The oversize fill also means that the gabions have been unable to be properly sealed along the top, instead they are secured at pinch points where the fill allows (A42, SGM 6082, October 2020)

Figure 10: Gabion wall with local building stone used to provide an attractive front face (note that the use of the baskets at ninety degrees to their normal orientation is not considered to be problematic). These gabion baskets were the only instance of double corrosion protection observed during the site inspections. (A38, no SGM number, January 2021)

Figure 11: Gabion-type wall with a significant proportion of undersized material that could be readily removed from behind the mesh by hand (M60, SGM 7066, October 2020)

Figure 12: Gabions used within a marine environment leading to significant corrosion and loss of fill. The upper gabions are becoming undermined which will eventually lead to loss of support for the slope above (A27/M3 Junction, SGM 10797, October 2020)

Figure 13: Gabions used within a marine environment leading to significant corrosion and loss of fill. The upper gabions are becoming undermined which will eventually lead to loss of support for the slope above (A27/M3 Junction, SGM 10797, October 2020)

Significant apparent vandalism was also observed at two separate locations; vandalism was observed where the mesh appeared to have been cut and this had led to loss of fill, either deliberately or from the action of gravity, and corrosion of the wire (Figures 4 and 14). Similarly, vehicle overrun appeared to be the cause of the damage to another Gabion Wall (Figure 15).

Figure 14: Vandalism of gabion basket which is located along a public footpath. The wire mesh appears to have been cut (A45/A46 Junction, SGM 9117, October 2020)

Figure 15: Vehicle overrun appears to be the primary cause of the significant damage to low height Gabion Wall at this location (A453, SGM 4025, October 2020)

Another environmental consideration is whether gabions should be used in areas with interfaces with the public.

It was also noted during the inspection that two SGMs were identified in the Geotechnical and Geotechnical Drainage and Management System (GDMS) as Gabion Walls that were not

of a basket form of construction. These comprised a galvanised mesh front face with reinforcing staples placed within the fill (Figures 8 and 11).

3 Design

3.1 Standards

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 (BSI, 2015). Other documentation available specifically mentions Gabion Walls, and refers to the design methodologies for gravity walls, for instance CIRIA C516 (Chapman et al., 2000) and Burland et al. (2012). These documents are shown in Table 1.

When it comes to specifications the guidance is clearer, with several sources of information for mesh products and geotextiles. Clause NG 626 of MCHW Series 600 gives standard specification details for type of gabion, mesh wires, corrosion protection and fill materials. Some construction guidance is available; however, this is not particularly comprehensive for Gabion Walls as it typically refers to the manufacturer's installation instructions.

The MCHW states that Gabion Walls on the network shall be manufactured and as such these will be considered a proprietary product.

3.2 Layout

There are a number of considerations for best practice for the design of a Gabion Wall layout and the following are reported in BS 8002:2015:

- A Gabion Wall should be built to a batter to increase its resistance to overturning and sliding.
- Gabion boxes with cages longer than 1.5 m should be fitted with transverse vertical diaphragm panels at 1 m centres to prevent undue distortion and stone migration. The edges of any diaphragm panels should be fixed to the sides by lacing or clips with 2.2 mm minimum binding wire, galvanized or PVC coated, to match the gabion mesh.
- Gabion units should bear down fully on the gabion below and not overhang the unit at the back by more than 150 mm, except in the case of a stepped revetment. Where gabion units do overhang, care should be taken to compact the backfill in the vicinity of and beneath the overhang.
- The cross section of a Gabion Wall should be proportioned so that the resultant force at any horizontal section lies within the middle third of that section.

The BS 8002:2015 states that in rivers and in tidal waters, consideration should be given to installing a filter behind the wall, to prevent the leaching of fines. Following the site inspections discussed in Section 2, it is recommended that the use of a filter/separator behind the wall should be considered in all cases.

The gabions shall be placed side by side and laced together to form a single gravity structure (Chapman et al., 2000).

Table 1: Matrix of relevant documentation available for Gabion Walls

Level of information provided: Background / Marginal / Comprehensive		Relevant to: Design	Specification	Construction
Publisher	**Document number and title**	**GABN**	**GABN**	**GABN**
BSI	BS 6031:2009 Code of practice for earthworks			
BSI	BS 8002:2015 Code of practice for earth retaining structures			
BSI	BS EN 10223-3 Hexagonal steel wire mesh products for civil engineering purposes			
BSI	BS EN 10223-8 Welded mesh gabion products			
BSI	BS EN 1997-1:2004+A1:2013a Eurocode 7: Geotechnical design - Part 1: General rules			
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			
NH	CD 622 Managing geotechnical risk			
NH	MCHW Vol 1 Series 600 Earthworks / Vol 2 NG 600			
ICE	ICE (Burland et al., 2012) Manual of geotechnical engineering			
NR	NRL3CIV071 (Network Rail 2011) Geotechnical Design			

3.3 Materials

There are two main components of which Gabion Walls are comprised: the mesh, from which the baskets are formed, and the fill material. The specification requirements for these are found in Manual of Contract Documents for Highway Works Volumes 1 and 2 (MCHW 1 and 2 Clauses 626 and NG 626, respectively) and are discussed in further detail within the sections below.

3.3.1 Mesh

Types of Basket

There are two types of gabion baskets which can be used on the network; woven gabions and welded mesh gabions and each type has its own specification requirements.

There is no specific guidance on when you would use one type over the other; however, they do have some differences that may cause the gabion to perform better for different applications.

Woven Mesh Gabions

- Are considered to be more robust and durable.
- They can accommodate substantial differential settlement.
- They are often used in demanding geotechnical applications.
- They are more difficult to fill and typically take longer to construct than welded mesh gabions.

Welded Mesh Gabions

- The welded mesh gabions hold their shape better than the woven mesh gabions and don't bulge out when filled.
- Installation tends to be quick and easy with the baskets being easy to fill.
- The welded mesh gabions can be value engineered and used to create bespoke walls (i.e. curved) and have the ability to utilise mixed mesh wire diameters to improve overall aesthetics and alignment whilst remaining cost effective.
- The welded wire is thicker, has higher tensile strength, yet as a result is more brittle and prone to breakage when exposed to stress and strain (Spiker, 2019).
- Welded mesh baskets are typically used in architectural applications or low height retaining structures where there is minimal risk of differential settlement (Maccaferri, 2021). With appropriate design they can be used as large retaining structures such as the 19m high mass gravity gabion wall at Jersey Airport which was constructed in 1968 (N Holmes, 2021, personal communication, 24 March).

The reason behind the difference in performance between welded mesh and woven mesh is governed by tensile strength. The tensile strength of woven mesh is defined by the interactions between the wires that compose the mesh. The tensile strength of the wire itself does not define the tensile strength of the mesh. In welded gabions, the tensile strength is defined almost exclusively by the tensile strength of individual wires and the welded connections between wires. When one of these connections is subjected to high levels of stress, breakage may occur, leading to a chain reaction of failure. In contrast, damage is naturally contained by the woven mesh in the case of individual wire breakage. This is because neighbouring wires and mesh are able to comfortably hold the additional load caused by the breakage of an individual wire (Spiker, 2019).

Wire

In accordance with the MCHW, gabion wire mesh units shall be woven steel wire conforming to BS EN 10223-3 (BSI, 2013b), or welded steel mesh conforming to BS EN 10223-8 (BSI, 2013c). The MCHW 1 Clause 626 states that unless otherwise stated in contract specific documents, woven steel gabions shall be of mesh designation 6x8 or 8x10 with minimum wire diameter of 2.7mm and welded mesh shall be 3mm to 5mm diameter bars with the aperture size 75mm x 75mm maximum. Following the site inspections this is still considered to be appropriate.

Corrosion Protection

In accordance with MCHW 1 Clause 626 unless otherwise stated in contract specific documents the site environment level shall be classed as High Aggressive: C4; and the Assumed Working Life shall be 120 years or greater. Clause 626 also states that the gabion mesh wire is required to be coated with zinc galvanised or zinc-aluminium alloy galvanised wire coatings *and* with a PVC (or other polymer) coating for additional durability. Following the site inspections this is still considered to be appropriate and necessary to achieve the required design life.

3.3.2 Fill

The MCHW Clause 626 states that unless otherwise specified, the gabion baskets shall be filled with Class 6G material complying with Table 6/1. This includes natural gravel, crushed rock, crushed concrete or any combination thereof and none of these constituents should include any argillaceous rock. During the site inspections the fill type used in the Gabion Walls varied greatly in performance, while primarily still meeting the MCHW requirements. It is therefore recommended that the requirements given in MCHW 1 Clause 626 be updated to say *'stone fill used in gabion walls should be sufficiently durable so as not to suffer deterioration sufficient to impair the performance of the system during the design life of the installation'*. This brings the recommendation broadly in line with BS 8002:2015 and would prevent the use of inappropriate stone fill.

The maximum size of fill material shall not exceed two thirds of the minimum dimension of the gabion compartment or 200mm whichever is smaller. The minimum size of the fill material shall be not less than the size of the mesh opening. Where larger facing stone is proposed to be used to provide an aesthetically-led front facing, a Departure from Standards shall be sought prior to the application. Larger stone should not be used internally as larger stone has the potential for joints to line up creating weak planes within the structure.

3.4 Environment Considerations

Prior to designing a Gabion Wall, it should be assessed as to whether the location is appropriate for a gabion solution.

Two gabion SGMs were observed in the same marine environment. Both appeared to be formed from galvanised wire and had suffered significant corrosion, loss of mesh, and consequent loss of fill. The mesh panels had completely broken off in places leading to rusted metal sticking out of the beach below posing a risk to the public (Figures 12 and 13). In these

cases, it begs the question if the design life of the galvanised wire was expected to exceed the design life of the SGM and if not, why was it selected as an appropriate solution?

In marine environments a stainless steel mesh would be more appropriate or an alternate solution such as a block wall or armourstone. In addition, Maccaferri advise against using welded mesh within water environments due to the risk of differential settlement (Maccaferri, 2021). This applies to all watercourses, not just marine environments.

Placing gabion baskets in areas in which vandalism may readily occur, including adjacent to public footpaths, especially where those using the footpath are shielded from view (Figures 4 and 14) for example, and the use of low height baskets where vehicle overrun may cause damage (Figure 15) should be very considered carefully.

3.5 Technical Approval

The approvals process set out in CG 300 shall be applied to all Gabion Walls formed from proprietary products, regardless of retained height. It is worth noting that CG 300 requires that Gabions that are not formed from proprietary products shall be designed from first principles.

All schemes involving geotechnical activities shall be subject to CD 622 *Managing Geotechnical Risk*.

There are a number of considerations to be undertaken prior to a design being agreed, the majority of which are related to the whole project such as safety, sustainability, traffic management and whole life costs.

With specific regard to the Gabion Wall design the following should be assessed:

- Is a Gabion Wall best suited for the environment?
- Is the Gabion Wall type (i.e. woven mesh or welded mesh) appropriate for the proposed application?
- Has the design considered the Gabion Wall in relation to global external stability, sliding, overturning and bearing?
- Has an appropriate foundation been designed for the Gabion Wall with regards to the ground conditions?
- Has a BBA certified product been obtained for the basket, and if not, why not? Have all manufacturer recommendations been reviewed and translated into the design and construction specification as appropriate?
- Is the design and specification in line with the requirements of the MCHW Volume 1 and 2 including the corrosion protection?
- Is the fill specified clean, hard, angular to round, durable, and of such quality that it suffers no significant deterioration, which would impair the performance of the system during the design life of the installation?

In accordance with CG 300 construction of the structure shall not proceed until the design or assessment certificates have been formally accepted by the Technical Approval Authority (TAA).

4 Construction

4.1 Materials

4.1.1 Mesh

Mesh Wire and Corrosion Protection

Issues identified during the site inspections highlighted that double corrosion protection was not always used and that the wire may be thinner than required; therefore, it is apparent that further enforcement of the specification is required by the Works Examiner

During construction, internal tie wires (bracing) should be inserted, and units tensioned in accordance with the manufacturer's instructions; failure to do this often results in deformed gabions. Gabion units should be constructed so as to maintain tightness of mesh and be laced securely with wire.

With all types of gabion baskets, quality and care during manufacture, transport, storage and construction (especially filling with stone) are required in order to ensure that the corrosion protection is not breached, allowing corrosion to commence. Cutting of the mesh to fabricate modified baskets will also create locations for corrosion to commence (Figure 5) and this is also often seen where mechanical pincers are used to install fastenings.

Modified Baskets

Typically, gabion baskets are prefabricated and in 'flat-pack' form and are assembled and filled on site. In recent decades the use of prefabricated gabions modified on site has become more prevalent and these were observed in numerous locations on the network. Such an approach is especially common in situations, for example, where a curved wall is required (Figures 2 and 3); however, the use of modified baskets is by no means limited to such instances.

It is recommended that modifying gabion baskets on site shall be reserved for only those instances in which recognised manufacturers cannot produce a prefabricated suitable solution. Any modifications should be done in accordance with manufacturer's instructions and will require agreeing as part of the technical approvals process.

4.1.2 Fastenings

There are three main types of fastenings recommended for gabion baskets and all three types were observed on the SRN during the site inspections:

- Lacing wire – This is the most common form of fastening and is often supplied as standard by the manufacturer with the gabions. The wire is used to continuously lace the baskets together and can be used on both woven and welded gabion baskets. This wire is also used to form bracing within the gabions to ensure support to the face.
- Clipping tools – These vary by manufacturer but typically comprise a galvanised or stainless steel metal clip which is compressed around two edges of the basket to join it together. The clips are often used in conjunction with lacing wire.

- Helicoil spring (also referred to as Helicals or Spirals) – These can be galvanised or stainless steel and can be used for welded baskets. These form the strongest connections and are also useful to reduce the probability of catching/snagging where gabions are used in public areas (Enviromesh, 2021). The helicoil spring was observed on one site during the inspections where the wall had been struck by a vehicle but due to the strength of the connection the top baskets were unaffected by the loss of support below (Figure 16).

Figure 16: Helicoil springs used on the vertical edge joins of the welded mesh gabion baskets. Lower gabions struck and damaged by vehicle but upper baskets have remained in place despite the lack of support below (A453, SGM 4025, October 2020)

4.1.3 Fill

The rock fill placed in a gabion basket is integral to the durability of the resulting SGM.

Gabion units shall be filled to fully achieve the requirements of MCHW 1 Clause 626.

The filling of gabion baskets must be undertaken with care so as not to damage the baskets and the associated corrosion protection and also to ensure that the fill is placed such as there are no significant voids and that materials cannot escape or be removed from the exposed mesh face(s).

While the filling of baskets by hand is preferred it is recognised that this is not always practical or economic. However, sufficient care to avoid damage to the wires is required and some hand repacking of the particles to ensure that the exposed face(s) are well-filled is usually essential. In such cases it is particularly important to get the bracing of the gabions correct during the filling process.

Attention to the minimum size of the fill is also required to minimise the likelihood of removal, whether by deliberate act or otherwise.

4.2 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).

4.3 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. A construction compliance certificate is required in accordance with the DMRB

It is important that snagging is undertaken (and completed) prior to the contractor leaving the site and that Works Examiner 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 is 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 Maintenance and Inspection

Gabion 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 Gabion 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 Detail

Visual assessments will, in almost all cases, be the most likely mode of inspection and will require the application of sound engineering judgement.

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 Gabion Walls:

1. Gabion Walls shall be assessed qualitatively. It is noted that quantitative judgements are difficult since conditions will vary greatly with the quality of fill used, type of basket, age, subsoil conditions, drainage, geometry, weathering factors and local expectations.
2. Local experience of the behaviour and comparison with past performance of the structure should be used to inform the assessment when available.
3. The inspection for assessment of Gabion Walls shall include the identification of the following:
   a) the type, size and shape of the gabion baskets;
   b) the condition of the baskets (i.e. unstitching, cuts or breaks in the mesh);
   c) the type of corrosion protection and its condition (for example is there any damage or loss of the corrosion protection);
   d) the age of the wall;
   e) the type and size of the fill used and its condition including weathering;
   f) the skill with which the fill has been placed (i.e. any oversize or undersized fill and any voids present);
   g) signs of bulging, leaning, spilling or other loss of profile;
   h) the provision or otherwise of drainage and the effectiveness of drainage where present;
   i) the existing loads carried by the wall(s) in terms of traffic volume;
   j) environmental stresses such as vehicle impacts or surface water;
   k) the presence (in and around the wall) of vegetation; and
   l) influence of trees and vegetation on the wall stability.
4. Assessment of Gabion Walls shall include a comparison with the performance of any adjacent structures.
5. Wall length, height, angle and condition of any retained slope should also be recorded.

5.2 Competence

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

6 Decommissioning

Safe decommissioning, or demolition, should be a consideration from the outset as required in CG 300 including the difficulty of taking down high/steep Gabion Walls and the provision of an alternative form of support to the retained material/structure. It should be noted that a Gabion Wall as a proprietary structure shall have a design life of 120 years.

7 Recommendations

Based on the walls inspected, which ranged from eight to 46 years old, there is no compelling evidence that when properly designed, specified, constructed and maintained, including an appropriate inspection regime, Gabion Walls cannot meet the required design life (120 years) of such SGMs.

Advice in standards and other related documents for Gabion Walls is well defined in some areas (such as specification) and limited in others (such as construction). 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.

Design and Specification

Recommendation 1: That as part of the design it should be ensured that the most appropriate Gabion Wall type (woven or welded mesh) is selected for its application.

Recommendation 2: That the use of a filter/separator behind the wall should be considered in all cases.

Recommendation 3: That the requirements given in MCHW Volume 1 Clause 626 be updated to (say) 'stone fill used in gabion walls should be sufficiently durable so as not to suffer deterioration sufficient to impair the performance of the system during the design life of the installation'. This brings the recommendation broadly in line with BS 8002:2015 and would prevent the use of inappropriate stone fill.

Technical Approval

Recommendation 4: That modifying gabion baskets on site shall be reserved for only those instances in which recognised manufacturers cannot produce a prefabricated suitable solution. Any modifications should be done in accordance with manufacturer's instructions and will require agreeing as part of the technical approvals process.

Recommendation 5: As part of the technical approval process it should be ensured that a Gabion Wall solution is the most appropriate for the environment. This includes careful consideration before designing Gabion Walls within tidal and marine environments, adjacent to public footpaths where vandalism is a possibility and low-height gabions placed in location where vehicle over-run is likely.

Recommendation 6: Gabion fill which does not meet the requirements of the MCHW should not be used on site unless there is a specific aesthetic requirement such as that shown in Figure 10. Any deviations should be discussed in advance and agreed as part of the approvals process.

Construction

Recommendation 7: Issues identified during the site inspections highlighted that double corrosion protection was not always used and that the wire may be thinner than required; therefore, it is apparent that further enforcement of the specification is required by the Works Examiner.

Recommendation 8: 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. A construction compliance certificate is required in accordance with the DMRB.

Recommendation 9: Any inspections for the acceptance of constructed Gabion 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 10: Construction quality assurance records for SGMs should be captured in the Geotechnical Feedback Report (GFR).

Recommendation 11: That the inspection of SGMs should be certified by a Geotechnical Advisor in accordance with CD 622.

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Appendix A Details of the Gabion Walls inspected

Gabion SGM ID	Area	Road	Eastings	Northings	Design Date	Construction Date	Age in Years	Type	Comment
4025	7	A46	456870	310200		2005	16	Welded	Unsure of age - GDMS suggests possibly 2005.
9117	9	A45	434231	275581	2003	2003	18	Welded	Unsure of construction date but assumed similar to design.
8552	8	A1	522568	238290		1994	27	Woven	No design information available but the road was constructed in 1994.
6082	8	A1307	524256	271326		1975	46	Woven	No design information available but the road was constructed in 1975.
10197	3	A27/M3 junction	469525	105476		2001	20	Welded	No design or construction date for the gabions. Revetment structure ('Fabriform' mattress and concrete blocks with bitumen joints) in the area were investigated by Mott McDonald in 1999/2000. This would place the age of the gabion revetments at (say) 2001 or later.
10198	3	A27/M3 junction	469392	105371		2001	20	Welded	
5281	10	M60	388654	390252	2007	2007	14	Welded	Unsure of construction date but assumed similar to design.
7066	10	M60	382432	390873	2003	2006	15	-	Not a gabion but a tied back reinforcing mesh.
7038	10	M60	380474	392493	2003	2006	15	-	Not a gabion but a tied back reinforcing mesh.
7630	7	A38	436275	340007		2013	8	Welded	
7761	7	A61	436386	339922		2013	8	Welded	
4435	7	M1	447166	335767	2009	2009	12	Woven	
10862	SW	A38	223331	64669	2008	2008	13	Woven	Unsure of construction date but assumed similar to design.

Forensic Examination of Critical Special Geotechnical Measures: Gabion 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, typically 60 year, design life and the design, specification and application of many of these techniques is based on limited studies. This Information Note is part of a series that reports on investigations of specific SGMs, in this case Gabion Walls, and makes recommendations on their future use.

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