SUSTAINABLE DEVELOPMENT OF ABERDEEN THROUGHT THE BERRYDEN ROAD IMPOVEMENT

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Abstract

Berryden Road is a catalyst for the traffic between the city centre, the northern Aberdeen and beyond. The road is incredibly important for the traffic network in the Aberdeen city and has been recognised as a road beyond its capacity anymore, resulting in considerable delays in travel time, particularly in peak times.

The project study involves widening the existing road and junction improvements between Skene Square and Ashgrove Road and constructing a new section of road between Ashgrove Road and Kittybrewster roundabout.

The project will provide sustainable benefits across the north of the city and beyond including improved journey times and connections, reduced congestion, improved pedestrian and cycle provision. It will also build on the benefits gained from the opening of Diamond Bridge, further improving connections within the city.

Keywords: *Berryden, Sustainable Development, road improvement*

Introduction

The purpose of this study is to detail in principle, the various sustainable structural design options (BS_ISO_20400, 2017) (Department_for_Transport, 2013) (DMRB-GD-01-15, 2018), for ground retaining solutions (BS-8006-1, 2010) at various locations along the Berryden Road, including consideration of land requirements, cost, aesthetics, engineering constraints. This study will also appraise each option in terms of best value, constructability, maintenance, aesthetics, where several options are detailed for a particular location, a recommendation shall be made. A few existing boundary walls and retaining structures along the Berryden corridor will be affected by this project. Where this is the case, actions required about these structures (remedial, demolition, alterations, tie-ins) shall also be discussed in this report.

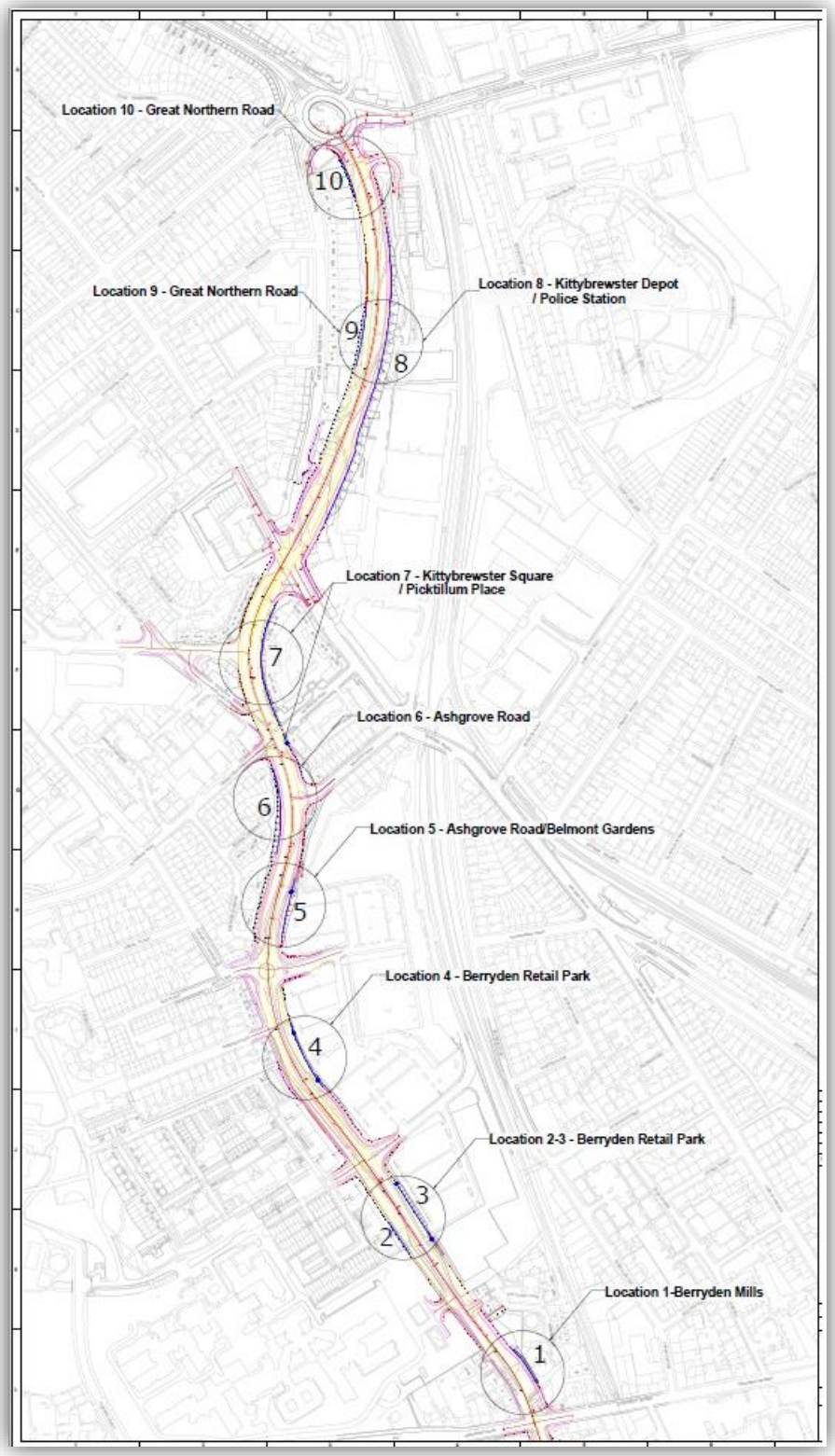
Retaining Structures Locations

Locations to be considered are:

	Chainage (m)	**Name**
Location 1	1330 to 1380	Berryden Mills
Location 2	1520 to1560	Berryden Retail Park (west side)
Location 3	1520 to 1590	Berryden Retail Park (east side)
Location 4	1720 to 1800	Berryden Retail Park
Location 5	1900 to 1960	Ashgrove Road / Belmont Gardens
Location 6	1990 to 2090	Ashgrove Road
Location 7	2110 to 2120 & 2130 to 2280	Kittybrewster Square / Picktillum Place
Location 8	2430 to 2680	Kittybrewster Depot / Police Station
Location 9	2550 to 2610	Great Northern Road
Location 10	2740 to 2770	Great Northern Road

The above general locations are identified in relation to the entire scheme in:

- Retaining Structures feasibility study - Locations Map



Location 1 - Berryden Mills - Chainage 1330m to 1380m

Description

At this location, the proposed road design includes broadening of the road on the east side for the creation of 2 carriageways. This will bring the eastern road edge and footway closer to an existing housing complex.

The existing ground level outside this building is lower than the current and proposed road levels, and footway levels and a retaining structure will be required to support the raised ground necessary for the road and east footway. The required retention height ranges from approximately 0.6m at the south end to 3m at the north end.

Technical Constraints

Existing made-up ground - The land between the housing complex and the existing road has previously been occupied by industrial buildings which have been demolished apart from one small building which houses an electrical substation which will also be demolished to make way for the new road configuration. It is likely that this raised area will comprise made-up ground, and its constitution may have implications for the engineering properties of the material. In this location, it may be necessary to excavate deeper than usually required, to reach a suitable subgrade for the construction of retaining wall foundations.

Private housing access - The existing housing complex can be accessed from the east footway via a footpath comprising three sections. The last of these three sections heads east to an access door. While the pathway can be altered, any new walkway will need to tie in with levels at the door. The gradient requirements may necessitate alterations to the footpath outside the currently planned land purchase area. Additional drainage measures may also be required to protect the housing complex from surface water runoff.

Retaining Wall Options

Two retaining wall configurations are considered (BS-EN-1997-1, 2004) possible at this location as follows:

Comparison of layout options:

	Advantages	**Disadvantages**
Option 1 – Retaining wall with footway at road level and separate access path to the building. (Department_for_Transport, 2018) (BS-8006-1, 2010)	Allows separation of pedestrian traffic with only resident and visitors approaching the building.	Requires separate access footpath to be closer to the building possibly impacting on the privacy of some residents.
	The second retaining wall only required over half of the section length and in higher ground. This would have a low retaining height.	
Option 2 – Retaining wall at road edge with footway along the exposed face and without separate parallel access path to the building. (Department_for_Transport, 2018)	No requirement for separate access footpath.	Requires second full-length retaining wall to retain footway with one half in the lower-lying ground, requiring a greater retaining height.
	Less land is taken up between footway and building.	No separation of pedestrian traffic apart from a single section of the footpath to building entrance.

		Footway is lower than road alongside the building, possibly presenting public safety/security concerns.

Four options are considered here for the type of retaining structures
For both options the retaining wall could be constructed in the following forms:

- Reinforced concrete cantilever wall (BS-EN-1997-1, 2004) – Comprises a horizontal base with vertical upstand. The L shaped concrete structure is sized to resist horizontal movement and overturning. Exposed faces can be visually enhanced by used of patterned formwork and coloured concrete. It is also possible to line the outer face with decorative masonry. See section 14 for details of possible finishes.
- Masonry retaining wall (ISTructE, 2013; Department_for_Transport, 2018) - Wall constructed of stone, blocks or bricks laid in mortar. Masonry retaining walls can be made wider in the lower levels to increase mass for resisting lateral movement. Larger masonry retaining walls (retaining height exceeding approximately 1.2m) can be constructed with vertical steel reinforcement bars cast into the foundations and the vertical part embedded in the masonry. Masonry units (block/bricks) can be selected for aesthetic appearance and strength. More decorative units would generally be used where visible. Masonry walls can also be rendered to achieve a suitable visual appearance. See section 14 for details of possible finishes.
- Reinforced soil retaining wall (ISTructE, 2013)– System comprising a wall of facing units secured from horizontal movement by geotextiles embedded in the retained material. Walls of this type range from steep grass slopes to vertical walls with a variety of finishes. See section 14 for details of possible finishes.
- Cast-in-situ contiguous concrete piles (BS-EN-1997-1, 2004) – This type of retaining structure is created by boring and casting a row of closely spaced circular concrete piles. The required level can then be excavated on the non-retained side of the wall. This wall can be lined and capped with masonry or patterned/coloured concrete to improve the surface finish.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Reinforced concrete cantilever (ISTructE, 2013) (BS-EN-1997-1, 2004)	Beneficial use of space with thin upstand.	Likely to be a more expensive option than masonry.
	Can be formed with patterned formwork or lined on the exposed side with masonry.	Relatively slow to construct
	Very low maintenance option.	
	Most suitable of the options for the incorporation of a pedestrian or vehicle restraint system.	
Reinforced masonry (BS-EN-1997-1, 2004)	Usually cheaper than reinforced concrete depending on the finish required.	Steel reinforcement required.
	Variety of finishes for appropriate aesthetics these can be in the form of the masonry units themselves or render coatings.	Relatively slow to construct

		Renders can be prone to cracking and de-bonding with water ingress. Render repairs likely to be required over the life of the structure.
		Repointing of mortar joints may be required at various stages throughout design life.
Reinforced soil retaining wall (BS-8006-1, 2010) (BS-EN-1997-1, 2004)	Quickest construction technique.	Requires geotextile anchoring in the ground to the retained side, this may present issues for future excavations and services works.
	Not prone to cracking	Less suitable for future changes than concrete or masonry.
	Can be constructed with aesthetically enhanced blocks or lined with masonry.	Pedestrian or vehicle restraint requires a separate system.
	Likely to be the cheapest option depending on the aesthetic finish required.	
Cast-in-situ contiguous concrete piles	Provides a means of reaching competent subgrade without prior excavation.	Structure alone is unsightly. Requires significant effort to hide and improve aesthetics.
	Low risk of undermining existing building foundations.	Specialist equipment required
		Substantial amounts of concrete required
		Likely to be the most expensive option
		Pedestrian or vehicle restraint requires a separate system.

Recommendation

It is recommended that a reinforced concrete retaining wall should be considered further. This option is durable, limited maintenance and can most easily include a pedestrian and vehicle restraint system. A textured finish using formwork liners (see Appendix) would be economic and give an attractive modern finish in keeping with the surroundings.

Location 2 - Berryden Retail Park (west side of the road) (Chainage 1520m to1560m)

Description

At this location, the preliminary road design shows broadening of the road for construction of 2 carriageways and footways. This requires the use of land in the upward sloping ground to the west side of the road. The neighbouring land to the west of this location is currently under development for housing.

A retaining wall is required on the west side of the road between chainage 1520 and 1560 where the proposed footway will cut into the existing embankment. The required retained height ranges from 1.1 to 1.8m. The existing boundary wall along the west edge of the footway is of stone masonry construction. This will be demolished to make way for the new road/footway

Technical Constraints

The location of this retaining structure may make it attractive to children. A Retaining wall of this height is likely to require edge protection (Department_for_Transport, 2013).

Retaining Options

For this location, the following forms of ground retention could be considered (ISTructE, 2013) (BS-8006-1, 2010) (Reid, 2008):

Option 1 - Reinforced concrete cantilever retaining wall – as described in section 3.

Option 2 - Masonry retaining wall – as described in section 3.

Option 3 – Reinforced Soil Retaining Wall - as described in section 3.

Option 4 - A graded slope could be used to contain the height change as an alternative to a retaining structure. A graded grassed slope of up to approximately 30 degrees gradient can be achieved without the use of soil reinforcement.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Option 1 – RC Retaining Wall (ISTructE, 2013)	Useful in this location if there is a requirement to maintain existing levels at the footway edge.	Most Expensive Option.
Option 2 – Masonry Retaining Wall (BS-EN-1997-1, 2004)	Useful in this location if there is a requirement to maintain existing levels at the footway edge.	Slightly less expensive than option 1
Option 3 - Reinforced Soil Retaining Wall (BS-8006-1, 2010) (Tensar-Tensartech-Systems, 2018)	Useful in this location if there is a requirement to maintain existing levels at the footway edge.	Requires space at the back of the wall for geotextiles to be bedded in the ground.This may present constraints for any future works on the retained side of the wall.
	Faster installation than other walls.	
	Likely to be the least expensive retaining wall solution.	
Option 4 – Grassed Slope (BS-8006-1, 2010)	Substantially less expensive than all retaining wall options.	
	Slope of approximately 30 degrees can be achieved within the proposed land purchase area.	
	No edge protection required.	
	No ongoing inspection requirements.	

Recommendation

It is recommended that option 4 (graded grass slope) should be considered further. This allows for the simplest engineering option and lowest construction cost. The effort required to maintain a slope (grass cutting) is likely to be similar to that of maintaining the proposed purchase area behind a full height retaining wall. There are no inspection requirements associated with this option.

Location 3 - Berryden Retail Park (east side of road) (Chainage 1520m to 1590m)

Description

At this location the proposed road broadening and new alignment requires use of ground between the existing east footway and a car park in the retail park. The existing ground in this area is occupied by a grassed slope and a retaining wall will be required to raise the ground level to that required for the proposed road and footway. The area to be retained is approximately 70 long between chainages 1520m and 1590m. The required retention height ranges from 0.7 to 1.5m along the length of the required wall.

The existing embankment to the retail park includes an access ramp and steps near the south end of the location. Further consideration will need to be given to the configuration and location of the replacement of these but for this study the following configuration is assumed:

- Ramp changed to approximately 20m long with single leg running parallel to footway.
- Steps changed by turning through 90 degrees, steps direction parallel to new footway.

The existing boundary wall along the west edge of the retail park is of stone masonry construction. This will be demolished to make way for the new road/footway.

Technical Constraints

Access ramp and Steps (BS_8300-1, 2018) - The existing access ramp and steps include masonry walls with painted metal railings and fence panels. The nearby retail premises also contain similar red brick masonry in the walls. Any replacement of the ramp and steps may require a similar construction. It is likely that the new ramp and steps configuration will need to be constructed in the same area as existing. The design will need to take into account any requirement for access to the side of the adjacent building, escape routes and any impact on parking.

Edge Protection (BS-EN-1317-2, 2010)– Edge protection will be required along the edge of the footway for the safety of pedestrians.

Retaining Wall Options

For this location, the following forms of retention could be considered.
Option 1 - Reinforced concrete cantilever retaining wall – as described in section 3.
Option 2 - Masonry retaining wall – as described in section 3.
Option 3 – Reinforced soil retaining wall - as described in section 3.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Reinforced concrete cantilever (ISTructE, 2013) (BS-EN-1997-1, 2004)	Good use of space with thin upstand.	Likely to be a more expensive option for others.
	Can be lined on the exposed side with masonry giving flexibility for future changes.	Relatively slow to construct
	Wall can be continued above the footway level if required for edge protection.	
	Very low maintenance Wall option.	
	Ramp and steps can be of the same construction.	

Masonry (Reid, 2008)	Usually cheaper than reinforced concrete	Likely to be thicker in lower sections or require vertical steel reinforcement.
	Variety of finishes for appropriate aesthetics these can be in the form of the masonry units themselves or by render coating.	Relatively slow to construct
	Wall can be continued above footway level if required for edge protection.	Renders can be prone to cracking and de-bonding with water ingress. Moreover, will require repair or replacement at various stages through the life of the wall.
	Ramp and steps can be of the same construction.	Repointing of mortar joints may be required at various stages though the wall's life.
Reinforced soil retaining wall (BS-8006-1, 2010) (Tensar-Tensartech-Systems, 2018)	Quickest construction technique.	Requires geotextile anchoring in the ground to the retained side. This may present issues for future excavations and services works.
	Not prone to cracking	Less suitable for future changes to finish than concrete or masonry.
	Can easily be constructed with aesthetically enhanced blocks or lined with masonry.	Likely to be less resistant to vehicle damage.
	Likely to be the cheapest option depending on the aesthetic finish required.	Cannot be continued above footway level for edge protection. Separate measures would be required.
		May not be suitable for construction of ramp and access steps.

Recommendation

It is recommended that options one and two should be considered further.

Of these options, masonry is likely to be less expensive but may have higher maintenance costs due to susceptibility render damage from water ingress or the need to re-point mortar joints. Both options can be extended to provide edge protection for pedestrians if necessary and have a range of aesthetic finishes available. A reinforced concrete retaining wall would be the lower maintenance option.

Further consideration should be given to:

- Land purchase about the access ramp and steps.
- ramp and steps construction and wall types
- continuity of appearance with other walls in the retail park
- continuity of appearance with existing stone boundary wall (to be demolished)

Location 4 - Berryden Retail Park (Chainage 1720m to 1800m)

Description

At this location, the proposed broadening and re-alignment of the road require the use of the land between the existing footway and the kerbed edge of the lower carpark. A grassed slope currently occupies this area, and a retention solution is required to raise the current level to that required for the proposed road and footway. The edge of the proposed footway will be near the centre of the existing grass sloped embankment. The retained height will range between 0.5 and 1m along the length of the wall. The existing layout includes an access ramp at this location, and a replacement will likely be required.

The existing access ramp wing-walls and lower walls of retail premises are of red brick. For the purposes of this study, it is assumed that the replacement access ramp will comprise a single 12m long leg running parallel to the proposed footway.

The existing boundary wall along the west edge of the retail park is of stone masonry construction, will be demolished to make way for the new road/footway.

Technical Constraints

The existing ramped (BS_8300-1, 2018) access ties into a footway in the car park, and this may be a requirement for the new ramped access. It may also be necessary and desirable for the replacement ramp to be of similar construction to the existing.

A retaining wall solution would require edge protection for the safety of pedestrians. This may be in the form of pillars with metal infill panels as used currently at other locations in the retail park. This could also be achieved by the installation of a fence, railings or by extending the retaining wall upwards to the required protection level.

Retaining Options

For this location, the following forms (BS-EN-1997-1, 2004)of retention could be considered.

Option 1 - Reinforced concrete cantilever retaining wall – as described in section 3.
Option 2 - Masonry retaining wall – as described in section 3.
Option 3 – Graded Grassed slope - as described in section 4.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Option 1 – Reinforced concrete retaining wall (ISTructE, 2013) (DMRB-GD-01-15, 2018)	Useful in this location if there is a requirement to maintain existing levels at the footway edge.	Most expensive option.
	Can be extended upward to provide edge protection if required.	
	Low maintenance retaining wall option.	
	Variety of aesthetic finishes available, including brick facing. Appearance can be changed in future.	
	Useful in this location if there is a requirement to maintain	Renders can be prone to cracking and de-bonding with

Option 2 – masonry retaining wall (Reid, 2008)	existing levels at the footway edge.	water ingress. Moreover, will require repair or replacement at various stages through the life of the wall.
	Can be extended upward to provide edge protection if required.	Repointing of mortar joints may be required at various stages though the wall's life.
	Variety of aesthetic finishes available.	
	Existing access ramp walls are masonry.	
	Slightly less expensive than option 1, depending on the finish required.	
Option 3 – Grassed slope (BS-8006-1, 2010) (Tensar-Tensartech-Systems, 2018)	Substantially less expensive than retaining wall options.	Independent edge restraint system possibly required.
	The slope of up to approximately 30 degrees can be constructed within the proposed land purchase area. This could likely be achieved without the use of soil reinforcement.	Grass cutting required on the slope (unless hard surface is used)
	Similar aesthetic appearance to the existing slope. This could also be changed to a solid surface such as monoblock if required for limited maintenance.	
	No ongoing inspection requirements.	
	Simple and fast construction.	

Recommendation

It is recommended that all options should be considered further. Of the two retaining wall options, masonry is likely to be less expensive but may have higher maintenance costs due to susceptibility render damage from water ingress or the need to re-point mortar joints.

Both options can be extended to provide edge protection for pedestrians if necessary and have a range of aesthetic finishes available.

A reinforced concrete would be the lower maintenance option.

Option 3 would have the lowest construction costs but higher maintenance requirements (for grass cutting) unless hard surfaced.

Further consideration should be given to:

- Retaining wall options chosen in other locations within the retail park.
- aesthetics of the existing stone masonry boundary wall
- requirements for maintenance

Location 5 - Ashgrove Road/Belmont Gardens (Chainage 1900m to 1970m)

Description

At this location, the proposed broadening and re-alignment of the road require the use of the land between the existing footway and the edge of the lower carpark. This area is currently occupied by a slope containing bushes and shrubs. A retaining structure is required at this location to allow the area currently occupied by the landscaped embankment to be raised to proposed road and footway levels. A retaining wall is required over a length of approximately 70m. This will vary in height between 0.7 and 2.4m. This retaining wall will be required to tie-in with the existing steps and access ramp at the north end of this location. The existing wall to the west of the proposed wall includes sections comprising blockwork pillars with metal infill panels and sections of ashlar stone wall. This wall is located at the top of the existing slope and is not a retaining wall.

Technical Constraints

Existing structures (BS-EN-1997-1, 2004)– The retaining wall will need to tie in with the existing steps and ramp which appear to be built on the slope rather than as a retaining structure. It is likely that temporary support to the steps and ramp will be required during construction.

Edge Protection (BS-EN-1317-2, 2010)- Edge protection will be required along the length of the retaining wall for the protection of pedestrians. This may be in the form of handrails, fencing or as at present in various locations in the retail park, with pillars and metal infill panels. Alternatively, the retaining wall could be extended upwards to the required level for edge protection.

Retaining Wall Options

For this location, the following forms (ISTructE, 2013) of retention could be considered:
Option 1 - Reinforced concrete cantilever retaining wall – as described in section 3.
Option 2 - Masonry retaining wall – as described in section 3.
Option 3 - Reinforced soil retaining wall - as described in section 4.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Option 1 - Reinforced concrete cantilever retaining wall	Good use of space with thin upstand.	Likely to be a more expensive option than others.
	Colouring and patterned formwork can be used to create a desirable finish. Can be lined on the exposed side with masonry giving flexibility for future changes to finish.	Relatively slow to construct
	Wall can be continued above footway level if required for edge protection.	
	Very low maintenance wall option.	
	Most suitable option for the installation of traffic or pedestrian restraint.	
Option 2 - Masonry retaining wall	Usually cheaper than reinforced concrete.	Steel reinforcement required
	Variety of finishes for appropriate aesthetics these can	Relatively slow to construct

	be in the form of the masonry units themselves or render coatings if required.	
	Wall can be continued above footway level if required for edge protection.	Renders can be prone to cracking and de-bonding with water ingress and may require repairs or replacement at various stages.
	Existing wing walls to steps are of masonry construction.	Repointing of mortar joints may be required at various stages through the wall's life.
Option 3 - Reinforced soil retaining wall	Quickest construction technique.	Requires geotextile anchoring in the ground to the retained side. This may present issues for future excavations and services works.
	Can easily be constructed with aesthetically enhanced blocks or lined with masonry.	Less suitable for future changes to finish than concrete or masonry.
	Likely to be the cheapest option depending on the aesthetic finish required.	Likely to be less resistant to vehicle damage.
		Can't be continued above footway level for edge protection. Separate measures would be required.
		Less suitable than other options for a tie-in with existing ramp and steps.

Recommendation

It is recommended that option one should be considered further. Reinforced concrete would be the lowest maintenance option and the most suitable for installation of pedestrian and vehicle restraint systems if required. In deciding on the wall type to be used, consideration should also be given to:

- The means for a tie-in with the existing steps and ramp.
- Retaining wall options chosen in other locations within the retail park.
- Aesthetics of the existing stone masonry boundary wall and masonry walls to access ramp and steps.
- Provision of support to existing steps and ramp structures during construction works.

Location 6 - Ashgrove Road (Chainage 1990m to 2090m)

Description

At this location, broadening of the road requires the use of land to the west of the existing road between location 5 (adjacent to Sainsburys Supermarket) and Ashgrove Road. The land to the west of the road is occupied by grass slope of the varying gradient. The proposed road and footway will cut into the grass slope over a length of approximately 100m. The required retention height ranges between 0.5 and 2.6m.

Technical Constraints
There are no known significant technical constraints concerning this site at present.

Retention Options

A graded grass slope (BS-8006-1, 2010)is the only option considered here. There is sufficient space available at this location to create a slope with a maximum gradient of 30 degrees. This can be achieved without the use of soil reinforcement. The advantages of a slope over any retaining wall are :

- Substantially less expensive than a retaining wall
- No inspection requirements
- Similar aesthetically to the existing slope
- No maintenance other than grass cutting as at present
- No requirement for edge protection

Recommendation

It is recommended that this option should be taken forward. There is no technical need for a retaining structure in this location. This option would also maintain a similar visual aesthetic to the existing.

Location 7 - Kittybrewster Sq. – Picktillum Place (South) (Chainage 2110m to 2120m)
Description

This location is at the junction between Berryden Road (east side) and Ashgrove Road. At this location, the proposed new road and footway alignment requires the use of land between the existing adjacent property boundary wall and the west outer-wall of a housing complex. A retaining wall is required to raise the ground level to that required for the proposed new road and footway alignment. The retaining wall will be approximately 10m in length and will have a maximum retaining height of approximately 0.8 - 1m.

Technical Constraints

Existing Structures (BS-EN-1317-2, 2010)– The existing boundary wall is of stone masonry construction, and its top level is approx 1.1m above the existing footway. The new retaining wall will need to tie-in to this structure at the south end. It may be necessary for the retaining wall to be curved to achieve tie-in of footways at the junction. The existing boundary masonry wall will need to be demolished north of the tie-in.

Retaining Wall Options
The following options are considered here:
Option 1 - Reinforced concrete cantilever retaining wall – as described in section 3.
Option 2 - Masonry retaining wall – as described in section 3.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Option 1 - Reinforced concrete cantilever retaining wall	Beneficial use of space with thin upstand.	Likely to be a more expensive option.
	Can be lined on the exposed side with masonry giving flexibility for future changes.	At this location, it is likely that both sides of the wall will need a decorative finish.

	Wall can be continued above footway level if required for edge protection.	Relatively slow to construct.
	Very low maintenance Wall option.	If a curved profile is required, this may be more difficult to achieve.
Option 2 – Masonry retaining wall	Usually cheaper than reinforced concrete	Likely to be thicker in lower sections of the wall
	Variety of finishes for appropriate aesthetics these can be in the form of the masonry units or with a render coating.	Relatively slow to construct. Some masonry types, e.g., stone masonry, may have higher material and labour costs.
	Possible to construct the wall using stone masonry or similar to maintain existing aesthetics on both sides of the wall.	Masonry walls and renders can be prone to cracking and de-bonding with water ingress.
	Low retaining height may allow construction without vertical reinforcement.	Repointing of mortar joints may be required at various stages though the wall's life.
	Wall can be continued above footway level if required for edge protection.	

Recommendation

It is recommended that both options should be considered further. Masonry is likely to be the least expensive option, but the use of stone masonry may increase the costs. A concrete wall could be lined with masonry, but if both sides need to match in appearance, this may be less practical a cost-effective than masonry. The adjacent housing complex walls contain both masonries finish and smooth rendered finishes while the existing boundary wall (to be partially demolished) is of stone masonry construction and the new retaining wall will tie-in with this. Further consideration should be given to:

- The requirement to blend aesthetically with the building and existing boundary wall.
- The requirements for both sides to have the same finish.

Location 7 - Kittybrewster Sq. – Picktillum Place (North) (Chainage 2130m to 2280m)

Description

At this location, the proposed road leaves Berryden Road/Blackhilton Road and follows a route between housing at Kittybrewster Square and Picktillum Place. The ground level of the housing to the east of the proposed road (Kittybrewster Square) is lower than the proposed road level, and the proposed layout encroaches on land currently inside the existing property boundary walls.

The existing boundary is in the form of masonry walls with a smooth coloured render. The walls retain small differences in level in places. It is likely that the new boundary walls will retain slightly higher level differences of up to 0.5m. The walls are topped with copes and painted metal fencing panels. The existing boundary wall will need to be demolished along the length of the new retaining wall.

Technical Constraints

Existing Structures - the proposed wall will need to tie in with existing boundary walls at both ends of this section and entrances to the housing complex.

The retaining wall is likely to require a similar aesthetic appearance to the existing boundary wall.

Road Noise (TRL, 2011) – It is possible that the proposed road upgrade will require a form of sound screening. A wall may provide some sound screening with the existing housing.

Wall Options

Retaining Wall Options

The following options are considered here:

Option 1 - Reinforced concrete cantilever retaining wall – as described in section 3.

Option 2 - Masonry retaining wall – as described in section 3.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Option 1 Reinforced Concrete Cantilever retaining wall	Good use of space with thin upstand.	Likely to be a more expensive option.
	Can be formed with patterned formwork and colour on both sides for an appropriate aesthetic finish.	At this location, it is likely that both sides of the wall will need a decorative finish.
	Wall can be continued above footway level if required for edge protection or noise screening.	Relatively slow to construct.
	Very low maintenance wall option.	Less versatile for the incorporation of fence panels, gates, and future modifications.
Option 2 – Masonry retaining wall	Usually cheaper than reinforced concrete	Likely to be thicker in lower sections of the wall
	Variety of finishes for appropriate aesthetics these can be in the form of the masonry units or with a render coating as with the existing boundary wall.	Relatively slow to construct.

	Possible to construct the wall using stone masonry or similar to maintain existing aesthetics on both sides of the wall.	Render coatings can be prone to cracking and de-bonding with water ingress. It is likely that render repairs will be required at various stages through the life of the wall.
	Low retaining height may allow construction without vertical reinforcement.	Repointing of mortar joints may be required at various stages though the wall's life.
	Wall can be continued above footway level if required for edge protection and to provide a boundary.	

Recommendation

It is recommended that both options should be considered further. It is likely that a smooth rendered masonry wall would be the less expensive option and would be more versatile for the installation of fencing panels and future changes, for example, the creation of a new opening. The reinforced concrete option is likely to have lower maintenance requirements than a masonry wall with a render coating. Both wall types can be extended upward for edge protection and noise screening if required.

Further consideration should be given to:

- the need to tie-in with and blend aesthetically with other walls in the area which are generally of masonry with smooth coloured render and fencing panels in places.
- the privacy of residents in the housing complex

Location 8 - Kittybrewster Depot / Police Station (East) (Chainage 2380m to 2680m)

Description

At the south end of this location proposed road passes over Clifton Road and then follows a course running over a brownfield site between the east side of the housing on Great Northern Road and the east side of City Council's depot and the Police Station at Kittybrewster. Retaining works are required on the east side of the proposed road to raise the existing levels to the levels required for the new road and footway. The required retention height ranges between approximately 1.3 and 4.6m.

Technical Constraints

Existing properties – The east side of the proposed road runs in relative proximity to the operational council and police sites, both of which contain assets which need to remain in place and operation. These include:

- Kittybrewster boiler house to the west of MOT inspection centre.
- Car Parking
- Scottish Water pump chambers.

A retaining wall solution is necessary to avoid disturbing these assets.

The proposed retaining wall alignment passes over the area currently occupied by the west end of a boiler house at the Council Kittybrewster Depot. Demolition of this structure will be required if the proposed retaining wall is to progress through this location.

Retention height – the required retention heights dictate that masonry options will not be economical at this location.

Retaining Options

Chainage 2380 – 2460m and chainage 2580m – 2680m. – In these locations, there is sufficient space for a slope to be constructed with a slope gradient of less than 30 degrees. (BS-8006-1, 2010) (Tensar-Tensartech-Systems, 2018) It is not necessary to consider a retaining structure at these sections. However, a retaining solution could be adopted if desired.

Chainage 2460 – 2580m – In this location, it is considered that a retaining wall is required. This will have a retention height ranging between 2.6m and 4.6m. (BS-EN-1997-1, 2004) (DMRB-GD-01-15, 2018) (ISTructE, 2013) The following options are considered here:

Option 1 - Reinforced concrete cantilever retaining wall – as described in section 3.
Option 2 - Reinforced soil retaining wall - as described in section 3.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Option 1 Reinforce concrete cantilever retaining wall.	No requirement for ground reinforcement works.	Likely to be the most expensive option.
	Less likely to present future problems for excavation or services works.	
	Most space efficient solution.	
	Wall can be continued above footway level if required for edge protection.	
Option 2 Reinforced soil retaining wall	Likely to be the least expensive option.	The requirement for geotextile anchoring may present issues for future earthworks and services works.
	Possibly simpler to construct (depending on existing services and anchoring requirements).	Wall cannot be continued above footway level to provide edge protection.
	Simple to provide appropriate aesthetic appearance.	

Recommendation

Chainages 2380m – 2460m and chainage 2580m – 2680m

In these locations, it is recommended that a graded slope should be installed rather than a retaining structure. A graded slope would be sustantially less expensive than a retaining wall option and would blend aesthetially with existing slopes the area. Edge protection for pedestrians and vehicle restraint may be required in these areas.

Chainage 2460m – 2580m

For this location it is recommended that option 1 (reinforced concrete retaining wall) should be considered further. This is the most space efficient option and does not require soil anchoring with geotextiles. Using this option, the wall can be extended upward to provide vehicle and pedestrian restraint. This is a low maintenance option and is least likely to negatively impact future excavation and services works on the retained side of the wall.

Further consideration should be given to the future of the boiler house at the Council Kittybrewster Depot as one end of this is on the proposed alignment of the retaining wall.

Locations 9 & 10 - Great Northern Road (Chainages 2550m to 2610m & 2740m to 2780m)

Description

Two locations are considered in this section. Location 9 is directly west of the road entrance to the Police Scotland depot at chainage 2550m to 2610m. Location 10 (chanage 2740m to 2780m) is near the end of the scheme where the proposed new road connects with the roundabout at the north end of Great Northern Road. The proposed layout requires use of land (at both locations) currently within the gardens to the east side of housing on Great Northern Road. This requires the road to cut through ground which is currently higher than the proposed road and footway. The required retention height is approximately 0.75 to 1.5m at location 9 and approximately 0.5 -1m at location 10.

Technical Constraints

Space Limitation – The space available within the existing and planned ownership area is sufficient for the construction of a vertical retaining wall but is insufficient for a slope or for the geotextile anchoring required for a reinforced soil retaining wall.

Depending on the future use of the land on the retained side of the retaining wall and the boundary type (e.g., fence or wall) to be installed, edge protection may be required along the exposed edge of the retaining wall.

The proposed alignment of the new retaining wall cuts through several property bounaries at these locations. Physical boundaries such as fences and walls will need to be demolished in places and support given to remnants which are to be preserved during construction.

Drawings also indicate the presence of at least 1 building within a garden which would require demolition to allow retaining wall works to proceed. Other buildings in gardens may require temporary support or protection during these works.

The demolition, preservation and replacement of structures and boundaries are likely to require a significant amount of design, preparation and construction effort in addition to the construction of a retaining wall.

Retaining Wall Options

The following options are considered here:
Option 1 – Reinforced concrete cantilever retaining wall – as described in section 3.
Option 2 – Masonry retaining wall – as described in section 3.

Comparison of retaining wall types

	Advantages	**Disadvantages**
Option 1 - Reinforced concrete cantilever retaining wall	Effective use of space with thin upstand.	Likely to be a more expensive option than masonry.

	Variety of finishes available including the use of colours and patterned formwork. Can also be lined on the exposed side with masonry giving flexibility for future changes.	Relatively slow to construct
	Exceptionally low maintenance wall option.	
Option 2 - Masonry retaining wall	Usually cheaper than reinforced concrete.	Likely to be thicker in lower sections of wall or require reinforcement.
	Variety of finishes available for appropriate aesthetics these can be in the form of the decorative masonry units or render coatings if required.	Relatively slow to construct
		Render coatings can be prone to cracking and de-bonding with water ingress. Render repairs likely to be required at various stages through the life of the wall.
		Repointing of mortar joints may be required at various stages though the wall's life.

Recommendation

It is recommended, that both of these options should be considered further. Option 1 - reinforced concrete, is likely to be the more expensive option but is less susceptible to render damage from water ingress and is likely to be a lower maintenance option.

A summary table of the recommended option is included below.

The recommended options for the various sites are:

- Reinforced concrete cantilever retaining walls
- Masonry retaining walls
- Retained soil retaining walls
- Graded grassed slopes

All of the above retaining wall options have a variety of aesthetic finishes available. Some examples of finished wall surfaces have been included in Appendix. Wall finishes are likely to have a significant bearing on the construction cost of the options chosen and cost estimation on the various wall options and finishes is recommended.

Where a masonry or reinforced concrete retaining walls have been included in design options in this report, it should be assumed that these are independent of any anchorages or soil reinforcements.

In the case of masonry retaining walls of up to approximately 1.2m retention height, these will resist lateral movement through self-weight, possibly with wider sections in the lower levels of the wall. Masonry walls with higher retention heights are likely to require reinforcement in the form of vertical steel reinforcement bars within the masonry and cast into the concrete foundation. Where render coatings are applied to masonry, these coatings have various life expectancies and cannot be expected to have the same life span as the structure of the wall. Replacement and repair of renders should be expected at various stages. Masonry may also require re-pointing of mortar joints in various stages.

Where reinforced soil retaining walls have been included in design options, these are assumed to require the use of geotextiles laid in the retained ground to provide resistance to lateral movement. The extent any geotextile anchoring would be dependant on the design loads and properties of the retained soils. Geotextile anchoring is likely to impact the potential for future excavation and services work in the vicinity of the retaining wall, and this should be a consideration in choosing a retaining wall option.

Grass slopes are recommended where possible as their construction costs are likely to be substantially lower than any of the retaining wall options. Slopes of gradient greater than 30 degrees (approx 1 in 1.7) are more likely, depending on soil properties, to require soil reinforcement. Where slopes have been recommended in this report, these could be formed to a gradient not exceeding 30 degrees.

Where footways are to be constructed adjacent to the top edge of the retaining wall or slope, these are likely to require edge protection for the safety of pedestrians. Vehicle restraint may also be required. Edge protection may also be necessary where slopes allow access (for example to children) from the footway to the top edge of a retaining wall. Reinforced concrete and masonry walls can both be extended in height to form edge protection or form a base for the installation of metal fence panels or similar. Examples of fence panels between masonry pillars can be seen in various photographs within this report. Of all the options given in this report, reinforced concrete is the most suitable option for the provision or mounting of traffic restraint.

Where graded slopes and reinforced soil retaining walls require edge protection or traffic restraint, these would require an independent system such as railings, fencing or crash barriers with vertical members sunk into buried concrete bases.

Summary of Feasible Options

Location	**Feasible Options**	**Recommendation**
1 – Berryden Mills	Reinforced concrete Masonry Reinforced soil retaining wall Cast-in-situ contiguous piles	Reinforced Concrete
2 – Berryden Retail Park (west side)	Reinforced concrete Masonry Reinforced soil retaining wall Graded grass slope	Graded grass slope
3 – Berryden Retail Park (east side)	Reinforced concrete Masonry Reinforced soil retaining wall	Reinforced concrete or Masonry

4 – Berryden Retail Park	Reinforced concrete Masonry Reinforced soil retaining wall	Reinforced concrete or Masonry
5 – Ashgrove Road / Belmont Gardens	Reinforced concrete Masonry Reinforced soil retaining wall	Reinforced concrete
6 – Ashgrove Road	Graded grass slope	Graded grass slope
7 – Kittybrewster Square / Picktillum Place (South)	Reinforced concrete Masonry	Reinforced concrete or Masonry
7 – Kittybrewster Square / Picktillum Place (North)	Reinforced concrete Masonry	Reinforced concrete or Masonry
8 – Kittybrewster Depot / Police Station	Chainage 2380 – 2460m and chainage 2580m – 2680m Graded Grass Slope	Graded Grass Slope
	Chainage Reinforced concrete Reinforced soil retaining wall	Reinforced concrete
9 – Great Northern Road	Reinforced concrete Masonry	Reinforced concrete or Masonry
10 – Great Northern Road	Reinforced concrete Masonry	Reinforced concrete or Masonry

Appendix

Retaining Wall Finishes – Manufacturer's Literature

- **Breedon Fyfestone**

Breedon Fyfestone is one of the largest manufacturers of architectural masonry and walling solutions within the UK construction industry.

- Elite Bullnosed: A sustainable reconstructed stonewalling range with the inherent beauty of fine-grained free stonewalling.
- Elite Pitched: Lightly hand dressed to give an accentuated, but stable convex appearance block for the perfect alternative to natural stone.
- Elite Split: Simple split finish and subtly blended shades faithfully reproduce the traditional dressed appearance of natural rustic stone and sandstone masonry.
- Elite Tumbled: A rugged finish gives this Elite Tumbled a beautiful worn, weathered appearance typical to traditional stone areas.

Table 1 summarises a list of the advantages and disadvantages of selecting Breedon Fyfestone Elite range.

Figure: Breedon Fyfestone Elite range sample of available colours.

Advantages	Disadvantages
Perfect for adding value and visual appeal to any commercial or domestic build. The outstanding aesthetic appearance that blends well in traditional natural stone areas. The perfect alternative to facing brick for specifiers seeking a more distinctive masonry appearance. Hand dressed finish reproducing traditional stone rock face characteristics. Cost effective block and most economical alternative to natural stone. Minimal maintenance and high density. 100% of the product can be recycled, thus reducing the amount of material that is sent to landfill. Produced in Scotland, with locally sourced materials under strict environmental and social legislation, for local supply. Excellent design life performance with proven long-term durability. Minimal maintenance and anti-graffiti coatings available.	Limitation of only fourteen available colours Potential maintenance issues with graffiti.

Table 1: Considerations to be taken into account when selecting Breedon Fyfestone Elite.

- **Granite Finish**

Granite is one of the most commonly used and widely occurring stones in the world. Granite is known for its properties of durability and retention of its colour and texture. This makes it very versatile and gives it potential for use in many different types of projects. Granite is an inherently variable material and some tonal variations may occur from time to time.

Figure: Silver/grey Cornwall granite.

There are hundreds of choices available to use as ranite walling and facing stone. The granite walling stone varies depending on its geology, colour, dimensions, age and the finish. When using granite, one of the most important considerations is source. A high quality stone can be ruined by bad building and a good stone mason can turn an average quality stone into a beautiful piece of building work.

When choosing a granite walling stone for building work it should chosen carefully,

Provided by Table 2 below are a list of advantages and disadvantages to be taken in consideration when selecting a granite finish.

Advantages	Disadvantages
Durable wear resistant and low maintenence. Design finishes to match existing profiles adding impact, aesthetic appeal and surrounding area of area and structures of Aberdeen. Variety of finishes and colours available to choose from. High quality stone Can be used as walling or facing.	Installation period lengthier than standard formliners. Expensive and not as cost effective. Potential maintenance issues with graffiti. Site won fill cannot be used. Specialist construction skills necessary.

Table 2: Considerations to be taken into account when selecting granite finish.

- **NOEplast Textured Formliner**

NOEplast is a durable, multi-use formliner system designed for the easy application of textured decorative finishes for both precast and in-situ concrete structures created by NOE. NOE is the only manufacturer to offer formwork use planning, formwork and textured formliners from the same source.

Figure: Capabilities of NOEplast textured formliner.

The textured formliners are highly flexible and tough shaped sheets of polyurethane. Placed in concrete formwork, the textured formliners mould and form the concrete surface to give it a third dimension. A unique glassfibre scrim provides them with strength and stability.

The strength and flexibility of the polyurethane (PU) material enables formliners to be used repeatedly, with at least 100 uses possible and more than 1000 in exceptional circumstances.

NOEplast is recyclable, UV resistant and dimensionally stable.

Table 3 provides a list of considerations to be taken into account when selecting NOEplast Textured Formliners given as advantages and disadvantages.

Advantages	Disadvantages
Cost effective, multiuse formliner systems. Capable of replicating brick, stone, timber. Design finishes to match existing profiles adding impact and aesthetic appeal to architectural concrete. Walls can be designed with features that add interest and deter graffiti. The design possibilities extend far beyond the 100+ standard designs available with bespoke designs possible. Formliners can be delivered preinstalled and ready for use to the precasting works or directly to site. NOE can carry out the formwork design, casting sequence and formwork use planning.	Installation period lengthier than standard formliners. Not as cost effective for smaller structures. Potential maintenance issues with graffiti. Site won fill cannot be used. A self-compacting concrete is needed containing superplasticisers that may be more expensive than a conventional mix.

Table 3: Considerations to be taken into account when selecting NOEplast Textured Formliners.

- **Render Finish**

Rendering is the process of applying a protective and durable wall covering to exterior walls and this can be done by hand or by machine.

The application process resembles the process for applying plaster. To ensure adhesion, the surface to be rendered has to be free of any dirt and loose particles and the surface roughened to improve adhesion. For large areas, vertical battens are fixed to the wall every 1 to 1.5 meters, to keep the render flat and even.

Figure 1: Examples of pebble dashed rendering.

There are numerous types of render ranging from traditional finishes (such as lime and sand and cement) to more modern advancements (such as polymer and acrylic).

Figure: Brick effect rendering.

Given below are some of the modern methods currently available:

- Acrylic render: is a finishing coat for render, containing acrylic aggregates to display an attractive finish. It is applied to new and existing render to seal the substrate layer and enhance the appearance of the elevation. Acrylic renders incorporate anti-cracking technology by using minute reinforcing fibres to produce an incredibly tough and durable finish.
- Brick Effect Render: is a versatile alternative to traditional brickwork and is ideal for use on projects where traditional new brick-work is impractical. It is applied in two coats. The top coat is then cut through to expose the base coat 'mortar' layer, thus creating the brick effect finish as shown by Figure .
- Polymer render: is a cement based system with specially selected polymers added to the mix. These polymers make the finished coat strong yet flexible, allowing them to be used on a number of substrates. Silicone water repellents are also an integral part of the premixed polymer/cement based render system. This silicone technology imparts a high degree of water repellence to the render surface whilst allowing water vapour to pass through the render, letting the substrate breathe.

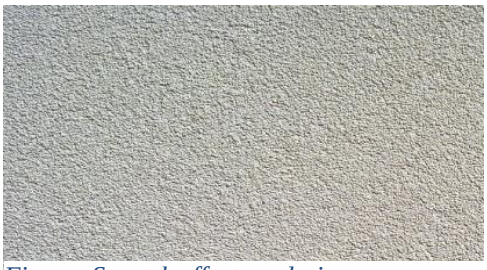


Figure: Scratch effect rendering.

- Scratch render: is a cement based render with a surface that looks similar to weathered stone when finished. It is applied in such a manner that the elevation of a property is made to look plaster flat. The surface of the render is then 'scratched' with a nail float. With a scratch render application the colour is never damaged and can be power washed back to brand new after many years.

Table 4 presents the advantages and disadvantages of selecting rendered retaining wall finish:

Advantages	Disadvantages
Various techniques available to select from. Capable of replicating brick work. Initial cost relatively cheap. Various colours to be chosen from depending upon the type of render technique selected. Walls can be self-cleaning depending upon the technique chosen.	Only a 20 to 40 year design life depending upon the rendering technique chosen. Liable to parts of render falling off and requiring expensive maintenance. Potential maintenance issues with graffiti. Areas of conservation may require masonry appearance.

Table 4: Considerations to be taken into account when selecting render finishes.

- **TensarTech GreenSlope**

The TensarTech GreenSlope System (Tensar-Tensartech-Systems, 2018) permits the construction of steeper slopes with the additional benefits of speed, versatility and potential savings on projects (of up to 75%) over alternative methods. The GreenSlope Earth Retaining System is used for building soil structures with a slope face angle up to 70˚. By selecting the GreenSlope System, it is both economical and attractive for steep slope construction with great aesthetic flexibility in the choice of materials than normally offered in traditional earth retaining schemes. The soil structure is effectively contained at the face by durable steel units which are joined using Tensar's highly efficient bodkin connection to the reinforced geogrid soil mass. The facing units are lined during installation with an appropriate erosion mat, which will help establish the chosen vegetative cover to the slope, whether that be a suitable ground cover, climbing plants or simply grass. The facing units are delivered to site, stacked and tied, ready to be lifted into position. During installation, the appropriate geogrid is connected using the Tensar bodkin. Brace bars are then fixed into position to hold the face at a constant angle allowing the easy placement of topsoil and structural fill behind the face.

Alignment is simple requiring no need for costly and time-consuming formwork necessary to maintain accurate alignment when using techniques such as 'wraparound'. The designer is able to choose a continuous 60˚ to 70˚ slope face structure or a terraced structure with step-backs built into the face to allow irrigation of the chosen vegetation at the face. The Tensar geogrids available provide core stability, which has been independently assessed and certified for use in structures with a design life up to 120 years in the most demanding situations. The cost-effectiveness and versatility of the GreenSlope offer many advantages over other traditional methods, such as traditional concrete structures and a more attractive solution than gabions or crib walling as well as providing a cost-effective solution to your earth retaining projects.

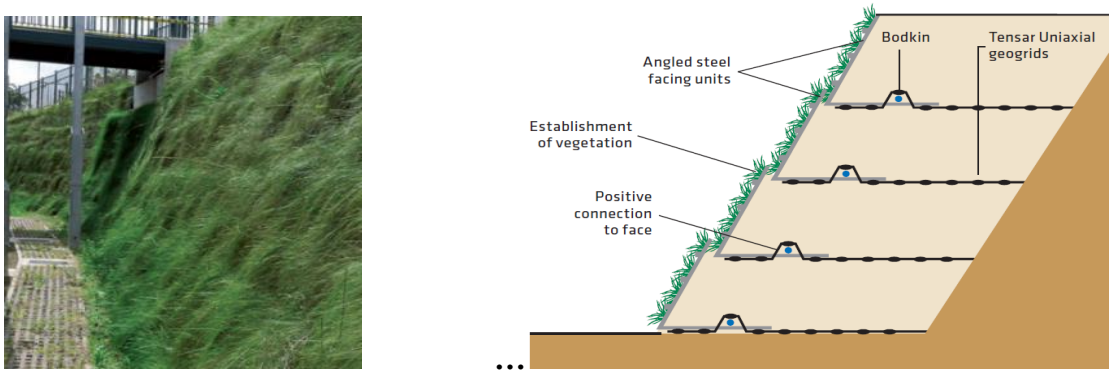


Figure: TensarTech GreenSlope example and cross section. Given below in Table 5 are list of advantages and disadvantages to be taken into account when selecting TensarTech GreenSlopes

Advantages	Disadvantages
Low cost earth retaining structure at a fraction of the cost of a reinforced concrete solution. Rapid and economical construction procedure ready for immediate use upon completion. No specialist construction skills necessary. Simple to build using established earth embankment construction techniques. Allows possible use of site won fill including cohesive or contaminated materials. Tolerant to differential settlement. Low bearing pressure may avoid expensive foundation treatment. he face can be detailed for vegetation. No external propping required. 120 year design life possible. Maximise the plateau area on a sloping site. Designed using BBA certified geogrids. Optimise the use of available space. Not possible to vandalise by graffiti.	Limited use for of continuous slope angles between 60˚ to 70˚. Requires additional spacing due to the constraining slope angle designs. Certain areas of conservation may require masonry appearance. Geotextile reinforcement restricts excavation at the top of the slope e.g. for utilities. Potential maintenance issues with steep vegetated slope. Vehicle/Road restraint systems, if required, would need to be set back from edge.

Table 5: Considerations to be taken into account when selecting TensarTech GreenSlopes.

- **TensarTech Rockwall**

TensarTech RockWall facing units are designed for the construction of reinforced soil walls with typical face angles in the range of 70º to 84º. Rockwall facing units are just one of several facing options available when specifying TensarTech Earth Retaining Systems as discussed in this report. With the RockWall System the ease and simplicity of a traditional gabion construction is gained but with a number of significant features.

Figure 2: TensarTech Rockwall example.

Internal and overall stability of the structure is provided by the geogrid reinforced soil mass, which is positively connected to the Galfan (zinc-aluminium alloy) coated steel facing units using Tensar's high efficiency bodkin joint. The method replaces the traditional mass gabion gravity structure with a single rock filled steel facing unit, securely connected to the geogrid reinforcement. This reinforced soil approach can provide cost and time savings by using only a single gabion thickness at the face whilst using lower cost fill (often site-won) in the reinforced soil block behind. Using high strength connection between the facing unit and the geogrid, rather than merely relying on friction, helps to ensure that the structure remains stable. As a result this fast and economical solution requires less imported rock

Figure: TensarTech Rockwall example.

material to fill its gabion-style basket facing and enables more site-won material to be used behind as fill reinforced with Tensar uniaxial geogrid. Using this approach can deliver significant material and construction cost savings, while achieving an attractive appearance.

Summarised in below in Table 6 is a listed of advantages and disadvantages.

Advantages	**Disadvantages**
Rapid and economical construction. Minimises use of expensive gabion fill 30% reduction in imported rock material compared with traditional gabion solutions can be achieved. Potential for face bulging minimized. May use site-won or reclaimed fill behind face. 120 year design life possible. Pre-tensioning of the facing units is not needed.	Limited use for of continuous slope angles between 70˚ to 84˚. Requires additional spacing due to the constraining slope angle designs. Certain areas of conservation may require masonry appearance. Geotextile reinforcement restricts excavation at the top of the slope e.g. for utilities. Potential maintenance issues with graffiti.

Table 6: Considerations to be taken into account when selecting TensarTech Rockwalls.

- **TensarTech TW Systems**

The TensarTech TW Wall Systems consists of pre-cast concrete modular facing blocks (at face angles of 82° to 90°) in combination with Tensar, high-density polyethene (HDPE), geogrids which reinforce the soil mass behind.

Figure: TensarTech TW System example.

There are two possible TW Wall Systems available for a selection called TW1 and TW3. Each system is based on reinforcing a soil mass with Tensar uniaxial geogrids allowing rapid and economical construction, reducing conventional construction times, avoiding the need for specialist skills and often enabling the utilisation of site-won fill materials. The TW Systems offer a combination of concrete modular facing blocks and reinforcing soil geogrids to create strong and durable retaining wall structures. A highly efficient connection is made between the facing block and geogrid creating a durable, strong, maintenance free retention system with a design live of up to 120 years (minimum 100 year design life). The high pH associated with concrete blocks does not affect the durability and functionality of HDPE geogrid reinforcement during the life of the structure.

Figure: TensarTech TW System example.

With savings of up to 50% on the cost of conventional reinforced concrete structures and potentially reduced construction, TensarTech Wall Systems offer proven solutions worldwide for the construction of retaining walls and other structures.

The large number of facing options (available in a choice of colours) allows the designer to create structures which consistently match the aesthetic and economic demands of the project, whatever the location and application. The distinctive and aesthetic quality of the facing blocks permit internal and external curves, corners, copings and stairs to be easily detailed allowing for easier and quicker installation making it possible to create strong architectural results easily and cost effectively.

Figure: TensarTech TW System example.

Additionally TensarTech's experienced engineers are able to help provide standard application suggestions to establish viability of their products and systems and enable planning costs, right through to preparing certified detailed design and construction drawings for using their products/systems on projects. Upon request, they can provide all necessary design certification and working calculations in a form ready for checking, with drawings issued for construction as well as all the crucial specification and installation details.

The cost-effectiveness and versatility of the TensarTech Wall Systems offers clients, specifiers and contractors many advantages over other traditional methods, such as reinforced concrete, for the construction of retaining walls. Given below in Table 7 is a summary of the advantages and disadvantages to be considered when selecting TensarTech TW Wall Systems:

Advantages	**Disadvantages**
Rapid and economical construction. Attractive range of modular block, finishes and colours that are adaptable to provide the aesthetic architectural effect. Durable with little or no maintenance. Often no specialist construction skills necessary. Greater tolerance of differential settlement Possibility of using site-won or recycled granular fill materials. Low bearing pressure may avoid expensive foundation treatment. External corner blocks and copings allow neat detailing. High efficiency connection between geogrid and facing unit, which is quick and easy to install and can easily accommodate tight concave or convex horizontal curves. Mortarless dry laid blocks that can be built without cranes or propping.	Limited use for of continuous slope angles between 82˚ to 90˚. Geotextile reinforcement restricts excavation at the top of the slope e.g. for utilities.

Table 7: Considerations to be taken into account when selecting TensarTech TW Systems.

Photos


Location 1


Location 2


Location 3


Location 4


Location 5


Location 6


Location 7a


Location 7


Location 8


Location 9


Location 10

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