WISH

Waste Industry Safety and Health Forum

FORMAL GUIDANCE DOCUMENT

CONTAINMENT WALL SAFETY (BUNKER, BAY, AND SIMILAR WALLS)

This guidance has been developed by the Waste Industry Health and Safety (WISH) Forum to help control safety and health risks in the waste management industry associated with containment walls, such as bunker, bay, push, and similar walls. The Health and Safety Executive (HSE) were consulted in the production of this publication. It endorses the sensible, proportionate, reasonable and balanced advice on managing risk during waste-related activities as set out in this guidance. This guidance was originally produced by the ESA (Environmental Services Association) Health & Safety Committee, to whom WISH is grateful.

This document is not a design guide and does not attempt to be exhaustive in covering all the situations that may be encountered. Anyone planning to erect a new storage bay or adapt an existing one should ensure that they have sought advice from a competent person.

The guide is presented in three sections: typical walls at waste management sites, specification, design and construction, and operation and use. It is aimed at:

- Owners, employers, supervisors, and managers responsible for the safe operation of waste processing and transfer facilities
- Maintenance and inspection operatives whose roles include working on walls
- Manufacturers, designers, builders, and any other person involved in the planning, specification, design, and erection of containment walls
- Safety professionals who may advise waste management companies and those working at such facilities
- All involved with the maintenance and inspection of containment walls

Contents

1. Introduction and applicable legislation and guidance

There have been a number of recent incidents in the UK, resulting in serious injury or death, involving the collapse of containment walls. These walls are widely used in the waste industry and there is a body of evidence highlighting a number of safety issues associated with their use.

1.1 Introduction

1.1.1 Containment walls on waste management sites have to cope with difficult conditions including; loading and unloading of waste, accidental impacts, wear from plant and machinery, and chemical attack from wastes and leachates from waste. The purpose of this guidance is to:

- Increase awareness of the issues surrounding containment walls in the waste and recycling industry.
- Share good practice with all those involved in the planning, design, construction, and use of such walls.
- Give guidance on the modifications which can been applied to such walls along with the methods to use to inspect & maintain such walls.

Owners and operators of waste facilities should read this information and determine if further work, and/or inspections, are required at their facilities to ensure the integrity of existing containment walls for the safety of all persons working in or close to containment walls.

For the purposes of this document ‘Containment walls’ are walls used in waste and recycling management facilities to hold back waste and/or material in a certain area either as a perimeter wall or a dividing wall between different areas of waste or recycling material. They are also commonly referred to in the industry as push walls and/or bay walls.

This document is intended for the waste and recycling industry including baled waste and recycling material, soils, wood, metals, textiles, etc. It should not be applied to containment walls used in other industries such as road salts, building merchants and/or and other industry not associated with waste or recycling management, although the principles contained in this document may apply.

1.2 Applicable legislation and guidance

1.2.1 The Construction (Design and Management) Regulations 2015 (CDM Regulations) are a framework for managing risk. They are intended to ensure that health and safety risks are properly considered during a project's development so that the risk of harm to those who have to build, use, maintain and deconstruct (at end of use) such structures, is removed or minimised so far as is reasonably practicable. Containment walls are structures and as such fall under these regulations. The CDM Regulations places duties on clients, designers, and contractors. The CDM definition of 'designers' includes anyone who specifies and alters designs as part of their work. This includes waste facility operators who specify or alter containment walls. A designer has a strong influence, particularly during the very early planning and design stages of a project.

1.2.2 Any proposal to locate containment walls external to a building should include liaison with the local Planning Authority, as planning consent may be required. Containment walls can by permanent or semi-permanent structures and may require planning permission. The planning authority will advise what actions need to be undertaken and may include impact assessments for appearance, noise, traffic, and the environment.

1.2.3 The Environment Agency have produced Fire Prevention Plan Guidance which will impact on containment walls where they are provided as fire segregation. WISH have also produced WASTE 28 which provides more guidance and best practice to reduce the risk of fires and spread of fires which may impact containment wall design.

2. How containment walls work and typical failure modes

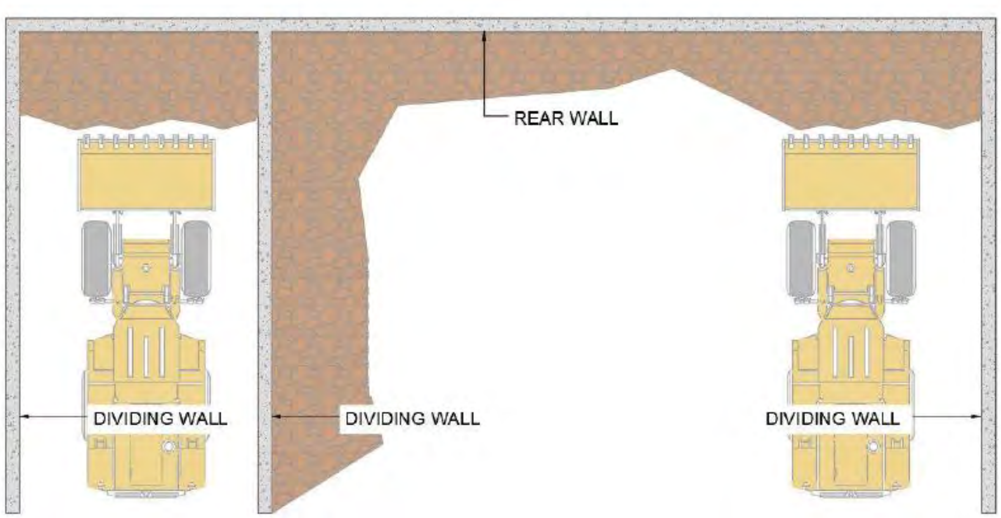
2.1 How containment walls work

2.1.1 The main purpose of containment walls is to separate and contain waste in their bays. This may be for bulking up and onwards transport, to act as a buffer for feedstock into a mechanical or biological process, to allow the material to mature (such is in Incinerator Bottom Ash, IBA, or green waste/compost) and/or to allow the material to dewater and leach (such as road sweepings).

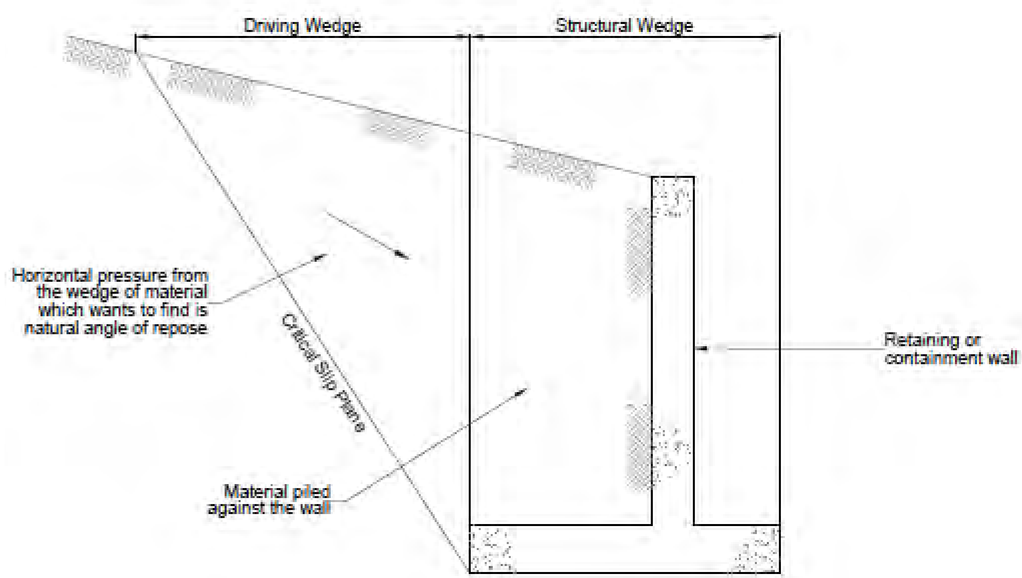
2.1.2 The intended purpose of the bay should be considered in the bay design as it will determine characteristics of the material in the bays (and how they may change over time), how the bay will be used (types of plant using the bay, vehicles needing to access the bay, etc) and conditions experienced in the waste bay, such as heating (in composting bays for example) or aggressive leachate (from food waste for example).

2.1.3 For the purpose of this guidance the containment walls of a waste bay are named as follows

- **Rear wall** – containment walls which waste are stored against and are the backstop to the waste when being pushed up or being scooped up for loading (note this is not a push wall and shouldn't be used as a wall to push or scrape against, as will be discussed in section 3 of this document)
- **Dividing wall** – containment walls which waste is stored against (usually on 2 sides unless it is the end of the waste bays) and runs perpendicular to the working face of the waste pile



2.1.4 A containment wall works similarly to a conventional retaining wall which holds back the ground in an abrupt change in level. The wall resists the horizontal force exerted on it from the wedge of material piled up against it, which would fall away if the wall wasn't present, see figure below:



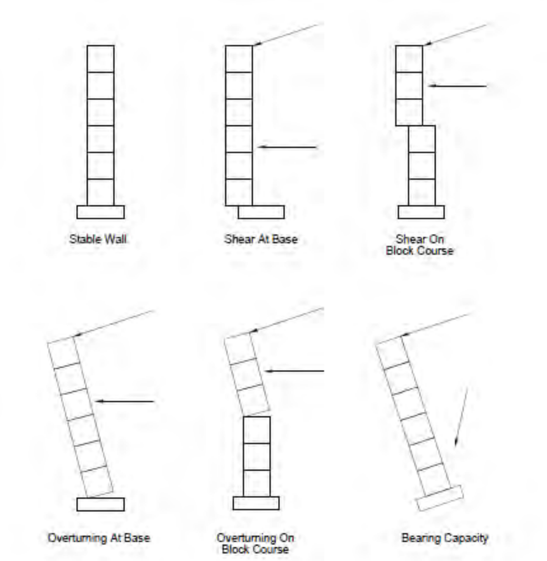
2.1.5 Typically, the wall transfers this load to the slab or foundation below to then be resisted by the ground. When a wall fails there are several typical modes of failure as shown in the figures below (note that these figures depict some of the wall types, but other types of walls can have the same failure modes).

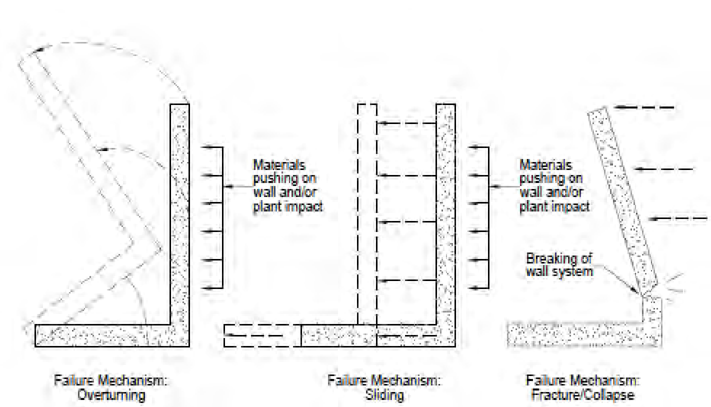
2.2 Typical failure modes

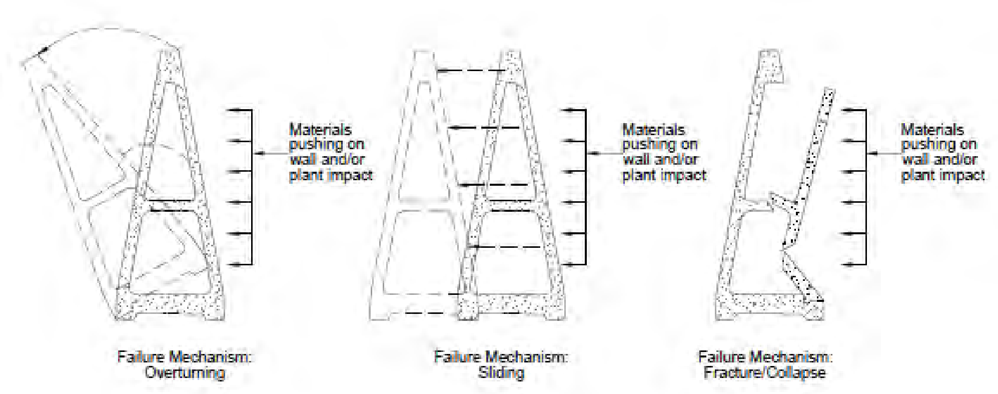
2.2.1 Typical failure modes include:

- Shear at base – this is where the wall shears the connection at the bottom of the wall or where the wall slides on its foundation (if it is not connected, such as interlocking blocks and freestanding precast concrete walls). In in-situ concrete walls it is possible for the wall to slide at the plane between the wall foundation and the ground below)
- Shear on a block course or shearing of the wall stem – this is where the wall slides between wall courses (for interlocking blocks) or shears in the height of the wall stem

- Overturning at base – this is where the freestanding wall/interlocking blocks overturns at the base or the wall, including the foundation, overturns
- Overturning of the block course or overturning in the wall stem – the wall overturns at the joint between block courses or causes the wall stem to fail and wall above the failure to overturn
- Bearing capacity overloaded – the ground below the wall and foundation fails and causes excessive movement and settlement causing overturning or collapse of the wall
- Earth slippage – more typical in walls where retained earth and ground below the wall can act as one. The earth below the wall and retained material slip causing the wall to move and fail







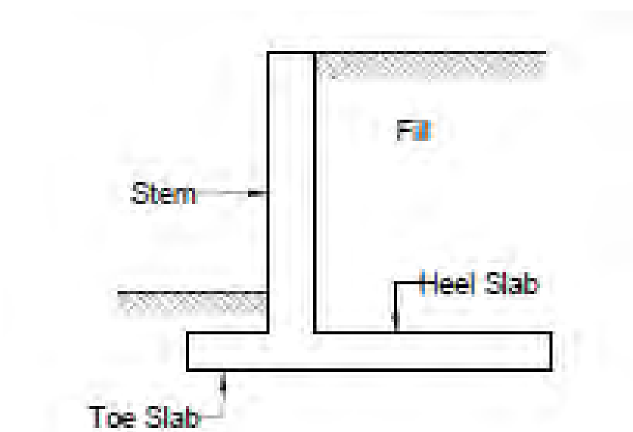
Top left - modes of failure of an interlocking block wall
Top right - modes of failure for L wall
Bottom - modes of failure for freestanding precast wall unit

3. Typical containment walls in waste management

Appendix 1 contains a matrix showing and summarising typical containment walls used at waste management sites. The sub-sections below give more detail.

3.1 In-situ reinforced concrete walls

3.1.1 In-situ reinforced concrete walls are typically formed by pouring and setting concrete around a steel reinforcement cage using temporary formwork. They usually have a stem and base (which is often concealed below the ground/slab) and have sections called the toe and heel. The wall transfers the horizontal loading to the base which distributes the force across the ground below. The base is typically thicker than the wall stem but is usually around 2/3 the length, compared to the wall height (but this can vary depending on conditions and loading). See figure below of a section through a typical in-situ reinforced concrete wall.



3.1.2 The stem of the wall resists the horizontal loading from the waste piled against it and accidental impact by transferring the load to the base and then the ground, converted into a vertical pressure on the ground below as well as horizontal sliding forces. The reinforcement in the wall gives the concrete tensile strength needed to resist the moments and shear forces and to transfer the load safely. The loading of the material on the heel of the wall (vertical load) resists the overturning caused by the horizontal load on the stem, along with the self-weight of the concrete structure.

3.1.3 The main failure modes on this type of wall are bearing capacity, where the loading on the ground causes excessive settlement and movement or failure of the wall stem causing shear or overturning in the stem. However, this would only tend to happen if there was high impact loading or if the integrity of the wall stem structure had been compromised (through heavy wear or damage to the concrete cover and/or reinforcement).

3.1.4 The positive features of an in-situ reinforced concrete retaining wall are as follows:

- Usually very good at distributing loads and resisting high accidental impact loads due to cast in-situ structure, continuity of the structure and connection between the base and stem of wall
- Typically, can give over 2 hours fire resistance required for walls between waste pile as per requirements of the Fire Prevention Plan Guidance, if the stem of the wall is thick enough, which it typically is under normal design circumstances
- Long operational life if designed, constructed, and operated correctly, with only minor maintenance
- Can be tailored to most shapes and sizes as it is a bespoke cast structure
- Small footprint, leaving move space for operations
- Good in internal and external conditions

3.1.5 The negative features of an in-situ reinforced concrete retaining wall is as follows:

- Expensive and time consuming to build compared to precast options
- Lack of future flexibility and reusability - once they are cast in place they can't be moved, replaced, or extended easily
- Can be difficult to repair and expensive, requiring specialist contractor and repair products, compared to exchanging a precast unit or block
- Over long periods can wear due to scrapping up of buckets, causing loss of cover (cover is the concrete between the face of the wall and the reinforcement, which protects the reinforcement from corrosion, typically 40-60mm thick) and even reinforcement wear and loss. This can be very difficult to repair

3.1.6 Typical issues that can occur with in-situ reinforced concrete walls are as follows:

- Wear damage to the stem of the wall through scraping up of the wall from front loader buckets
- Inconsistent quality of wall is possible as it is a cast on site material and is dependent on the quality of the mixing, pouring, and curing of the concrete
- Localised damage caused by operations vehicles (such as gouges in the concrete) causing lack of cover
- Weakening of the concrete can occur from chemical attack from leachate, particularly from organic waste streams, such as food waste, green waste, and residual waste

3.1.7 Some best practice ideas for the design of the in-situ reinforced concrete walls are as follows:

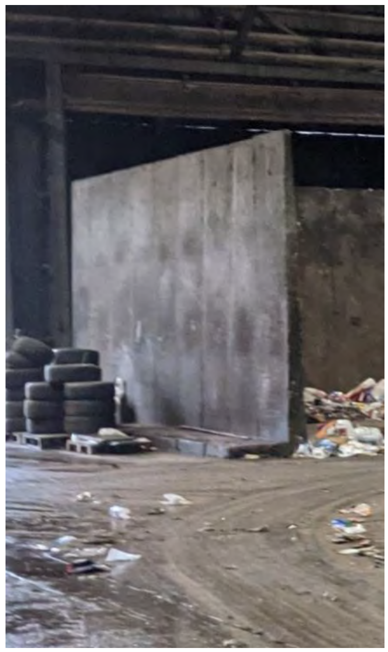
- The use of a wear plate on the lower section of the wall to act as a sacrificial layer and protect the concrete and the cover (see photograph below). This wear plate should be fixed to the wall after the wall has been constructed, have countersunk fixings, and should be set into the slab slightly at the bottom to prevent the joint at the bottom of the wear plate being damaged (the base of the plate can then be grouted into the slab).

- Increase concrete cover to the reinforcement in the wall stem as much as possible
- The use of high strength, chemical resistant and wear resistant concrete mix design
- If possible do not incorporate the base of the wall with the slab, allow the slab to be formed above the base so that the kicker of the wall stem can be hidden in the depth of the slab (the cast joint in the concrete between the base pour and the wall stem pour which is often a weak point). It also means slab wear will not cause damage to a structural member (wall base) and the slab can then be easily broken out and recast in the future, as part of maintenance

3.2 Freestanding or bolt-down precast concrete wall units ('A' frames, tapered walls, 'L' shaped walls etc)

3.2.1 For brevity, these walls will be referred to as precast concrete wall units. They come in many different shapes and sizes with different bolt down options and interlocking arrangements. Some unit even have specific corner units to allow the walls to meet or change direction at 90 degrees. These walls are precast concrete (cast off site and transported to site for installation) and have concrete poured around steel reinforcement cages.

3.2.2 Most are wider at the bottom of the wall and taper towards the top either with a consistent taper (like in an A frame) or a more abrupt taper at the bottom of the wall which leads to a narrow wall stem. Most of these units are hollow, although some do have more solid concrete sections at the bottom of the wall. Most have the option to bolt down the wall units to the slab or foundation below using holding down bolts. Typically used as dividing walls between waste bays but can also be used to all sides of small waste bays. See photographs below for example different type of precast concrete wall units.



3.2.3 The walls resist horizontal loads using self-weight and the friction between the wall and the slab below for overturning and sliding respectively when the walls are not bolted down. When the units are bolted down, they use self-weight and the weight of the slab/foundation it is connected to, to resist overturning. Bolted down units resist sliding through the connections to the slab below. The units impart forces to the slab and ground below which both need to be suitable to resist these concentrated loads.

3.2.4 The main modes of failures for these types of walls are sliding of the wall unit on the slab below (when not connected with bolts), overturning of wall units (when not connected with bolts) and bearing pressure failure if they are supported on an unsuitable slab and/or ground, for the loading. The bolts can often fail due to excessive impact loading causing the units to act like freestanding walls again.

3.2.5 The positive features of precast concrete wall units are as follows:

- Quick and relatively inexpensive to install, often with quick lead times as they can be purchased off-the-shelf
- Constant quality of construction associated with factory formed and cured concrete
- Quick to replace damaged sections
- Flexible to be able to reposition walls as operations change and waste streams change
- Good in internal, and external, conditions
- Come in a range of heights and shapes so likely there will be one that suits the need

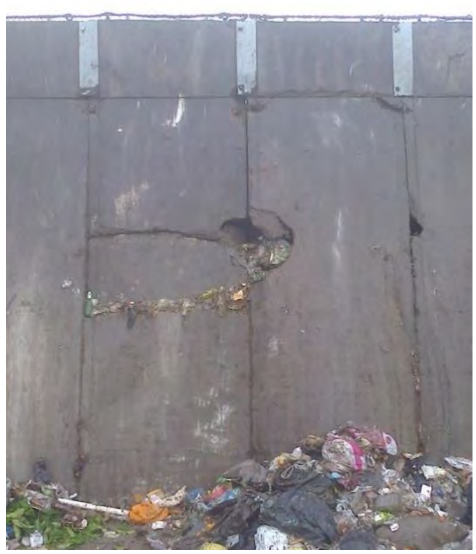
3.2.6 The negative features of precast concrete wall units are as follows:

- Large bottom of the wall compared to the top can lead to damage of the bottom of the wall as machine operators find it more difficult to work against and locate under a waste pile
- Surface features (such as straps used to connect some types of units) become damaged easily and can corrode easily as they are typically steel
- Holding down bolts known to fail if overloaded through accidental loading, making the wall act like it is freestanding
- Freestanding walls known to slide out of position if slightly overloaded and sometimes even topple
- Thickness of wall sections and joints can cause issues if these walls need to act as minimum 2-hour fire resistant walls, as per Fire Prevention Plan Guidance. Some walls are thick enough and might be suitable if the joints are sealed suitably with an intumescent compound
- Some units have very little interlocking leading to units acting independently
- Relatively thin cross section which isn’t as robust against impact loads (compared to in-situ and mass concrete interlocking block) leading to shorter lifespans in waste management facilities (typically 10-15years), but they are easy to replace
- Some unit types design makes inspecting the holding down bolts near impossible after installation of wall units as they are hidden inside the wall cavity
- Waste can collect in the cavities (where present), which can be an attractive nesting place for rats and other pests
- Only work in right angle bays and the corner pieced at right angle joints are often steel plates which aren’t robust

3.2.7 Typical issues that can occur with precast concrete wall units are as follows:

- Individual wall units holding down bolts fail leading to sliding or toppling of walls (see photograph below)

- Loss of strapping at joints on some wall unit types
- Movement of wall units which aren't bolted down under forces from site plant impact
- Localised damage caused by vehicles (such as gouges in the concrete) causing lack of cover
- Wear is possible but shape of units tend to mean that scraping up against is harder (shape of L walls still makes it more susceptible)
- Localised damage caused by operations vehicles due to thin sections of concrete which are less robust (see photograph below of damaged wall with straps removed)



- Chemical attack from leachate, particularly from organic waste streams, such as food waste, green waste, and residual waste, which can weaken the concrete
- Base of L wall sticks out on one side meaning it can be a hindrance to operations if used as a diving wall between 2 waste bays

3.2.8 Some best practice ideas for the design of precast concrete wall units are as follows:

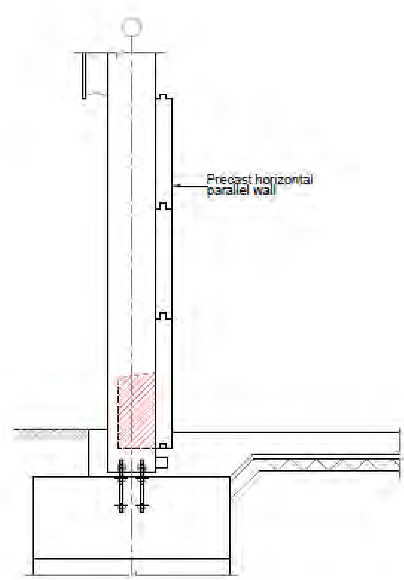
- Always bolt down to the slab to prevent accidental impact loading causing sliding or toppling of wall units
- Fill void with concrete if reasonably practicable, which some manufacturers encourage under certain conditions
- The use of a wear plate on the lower section of the wall to act as a sacrificial layer and protect the concrete and the cover
- Use end plates to close voids at the ends of walls and to highlight the profile of the wall (see photograph below)

3.3 Horizontal pre-stressed precast concrete panel walls

3.3.1 Horizontal pre-stressed panel walls are solid precast concrete sections with prestressed tendons/wires to preload the concrete section. The wall panels are usually standard thicknesses and heights, which can be stacked on top of each other to give the total wall height required. The panels typically span to a supporting structure, usually a steel column which is part of the building structure, but it can also be to cantilever columns which are solely used to support the wall panels.

3.3.2 The bottom wall panel sits on the slab below. The wall panels are usually fixed to the columns using a clamp system with a threaded bolt and a threaded socket which is cast into the wall panel. The wall panels could also sit between the flanges of an 'I section' steel column or a parallel flange channel, which is often use when the wall is loaded on both sides. See photograph below of this wall system.

3.3.3 The wall panels transmit the horizontal load to the supporting structure which then transmits this load to its foundation, which in turn transmits this load to the ground. Hence, the wall essentially shares the buildings foundation. However, this has to be allowed for in the design of the supporting structure, wall panels should not simply be added to an existing structure without first checking the structure, and its foundation, is suitable. See diagram below for a section through this wall system.



3.3.4 This type of wall is very different to the other options and so its failure modes are different as well. Bearing capacity failure is still possible but this would be the building structure or the cantilever posts foundation. Most common failures seen in this type of wall system is shearing of the panels from accidental impact force or panels becoming dislodged due to movement of the clamp systems. Both can result in whole panels or a series of panels falling as they are stacked one above another.

3.3.5 The positive features of pre-stressed wall panels are as follows:

- Quick and relatively inexpensive to install
- Constant quality of construction associated with factory formed and cured concrete
- Quick to replace damaged sections
- Can be used in both internal and external environments
- Small footprint, leaving move space for operations
- Can be made to any span, up to a point, meaning they can fit the design of the steel structure required
- No need to build an individual foundation, they can be combined with the building structure's foundation
- Can easily be extended higher (provided the supporting frame can allow it and the extra load it will attract)

3.3.6 The negative features of pre-stressed wall panels are as follows:

- Thickness of wall sections and joints can cause issues if these walls need to act as minimum 2-hour fire resistant walls, as per Fire Prevention Plan Guidance. Some walls are thick enough and might be suitable if the joints are sealed suitably with and intumescent compound. Unlikely to be suitable if held between steel columns or posts (rather than clamped to the face of them) as these will conduct the heat of the fire
- Typically, thin sections which aren't as robust against impact loads (compared to in-situ and mass concrete interlocking block) meaning they often have shorter lifespans in waste management facilities (typically 10-15 years. However, they are easy to replace
- Clamp system which ties the wall to the steel supports often hidden in the void between the cladding and the wall making inspection difficult
- Inflexible once build in terms of repositioning as they are dependent on the supporting structure (steel frame building or cantilever posts and their foundations)
- Over long periods can wear due to scrapping up of buckets, causing loss of cover

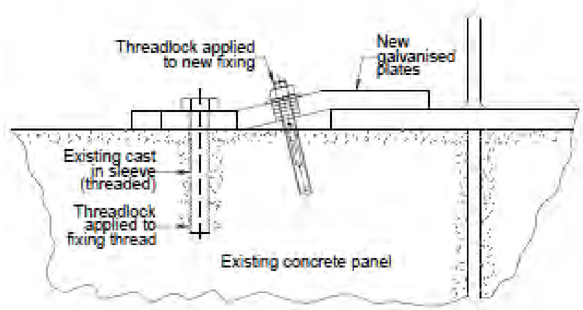
3.3.7 Typical issues that can occur with pre-stressed wall panels are as follows:

- The clamp system can come loose, and a panel can become disconnected from the supporting structure leading it to fall out (usually leading to any panels above it falling out). Often the clamps are hidden between the wall and building cladding, so inspection isn't possible to know when this is occurring (see photographs below)
- Horizontal joints between walls and at the bottom of the walls tend to get snagged by buckets leading to them being dislodged and camps moving
- Horizontal joints have a tongue and groove interlocking system which often causes spalling of concrete on the grooves as the panels move independently under accidental impact loading
- Panels can crack through the thickness of the section due to high accidental impact loading, leading to them failing
- Localised damage caused by operations vehicles (such as gouges in the concrete) causing lack of cover
- Weakening of the concrete can occur from chemical attack from leachate, particularly from organic waste streams, such as food waste, green waste, and residual waste
- Wear damage to the wall panels through scraping up of the wall from front loader buckets

Top left – clamps in correct position
Top right – loose bolt with rotated clamp
Bottom – collapsed horizontal wall panel

3.3.8 Some best practice ideas for the design of pre-stressed wall panels are as follows:

- To reduce the chance of the wall clamps rotating when they come loose, use a second fixing on the clamps to stop them from rotating and use a thread locking compound to reduce the chance of the bolts coming loose, see diagram below of clamp with double bolt fixing
- Keep the clamps exposed for inspection and maintenance, i.e. finish cladding at top of wall level if possible. This is beneficial to all walls at the perimeter of the building as the cavity between the cladding and the wall often fills with waste and becomes a nesting site for rodents and other pests found on waste management facilities
- The use of a wear plate on the lower section of the wall to act as a sacrificial layer and protect the concrete and the cover. This wearing plate should be fixed to the wall after the wall has been constructed, have countersunk fixings and should be set into the slab slightly at the bottom to prevent the joint at the bottom of the wear plate being damaged. If the wear plate is big enough to cover the first horizontal joint up from the slab, it also protects this from being snagged by the front loader bucket



3.4 Vertical pre-stressed precast concrete panel walls

3.4.1 These walls are also precast pre-stressed reinforced concrete wall panels, but the panels cantilever vertically from an in-situ reinforced concrete base. They act very similarly to in-situ reinforced concrete walls. The main differences being:

- Somewhat quicker to install as the wall stem doesn't need to be cast on site
- The joints and the thickness may mean they aren't suitable as a 2-hour firewall
- Wall stem is typically thinner than the in-situ options making them less robust to impact loads (apart from options which have a cavity in the precast stem which are to be filled with in-situ concrete)
- Tongue and groove joints between panels can lead to spalling of panels as they move separately to each other under accidental impact loading

3.5 Interlocking mass precast concrete block walls

3.5.1 Interlocking concrete blocks are popular and widely used in waste and recycling, particularly where there is an existing concrete base. These walls are made up of large precast concrete blocks which are built like a conventional blockwork wall but with dry joints (no mortar). They are connected together with interlocking nibs and sockets located at the top and bottom of the blocks respectively. The walls sit on the slab or foundation below with no connection to the floor. The blocks come in different widths, height, and lengths to allow them to be built in various lengths and configurations. The walls are always built with a running bond (like in a typical brick wall) to link the wall blocks together. For higher walls use spreader bottom block and/or rotate the bottom course of blocks by 90 degrees on plan, if possible. See photograph below which is an example of an interlocking block wall.

3.5.2 These walls use their substantial self-weight to resist the horizontal loads form the retained material. The weight of the wall resists the overturning force and the friction with the slab or foundation below resists sliding of the walls at the bottom of the wall. The nibs between the blocks help to transfer the horizontal loads down to the bottom of the wall and share loads between blocks.

3.5.3 The main modes of failures for these types of walls are sliding of the wall at the bottom of the wall, at the point of connection between the wall blocks and their foundation or slab. These blocks can also overturn if overloaded due to the lack of fixing to the foundation of slab below. Bearing capacity failure can also be a problem due to the weight of the wall and the horizontal loading concentrating this load towards the edge of the wall. Shear in a block course and overturning in a block course is possible but would usually only happen if they were struck very hard at high level.

3.5.4 The positive features of the interlocking concrete blocks are as follows:

- Quick to install and can be brought off the shelf so lead times are usually short
- Flexible in terms of repositioning walls, altering heights and replacing blocks
- Thickness means they are very robust against impact loads
- No reinforcement makes wearing less of an issue as there is no cover to compromise
- Constant quality of construction associated with factory formed and cured concrete
- Good in internal and external conditions
- No need for foundation of the wall (this assumes the slab and ground below is suitable to support the wall)
- Typically, can give >2 hours fire resistance required for walls between waste pile as per requirements of the Fire Prevention Plan Guidance, but some blocks might require the joints to be sealed to achieve this
- Likely to have a long lifespan (typically 20-25 years in a waste management facility)

3.5.5 The negative features of the interlocking concrete block walls are as follows:

- Need to establish to establish whether the concrete base can take the loads involved. Often the supplier will design the wall but will pass the responsibility for the design of the slab to the client
- Take up a large space in the building due to their thickness
- Centre of gravity is not weighted to the bottom of the wall like with most freestanding walls, this can be an issue if the supporting slab isn't level, causing the wall to be out of plumb vertically
- Lack of fixing to the foundation or slab means over time the walls can move slightly causing a banana shape in the wall on plan, usually between returns or buttresses in the walls (due to tolerance in nibs and sockets which allow small movement
- Can be misused by stacking higher than designed and creating dangerous circumstances which may lead to collapse
- Very heavy blocks which might overload the slab and ground below
- Large amount of concrete used in forming blocks and transporting them to site means walls are less sustainable than other options
- Walls are critically sensitive to the slab they are supported on, in terms of its flatness, slope and suitability to dissipate the weight to the ground below

3.5.6 Some best practice ideas for the design of interlocking block walls are as follows:

- High weight and lack of fixing to the base means the suitability and integrity of the concrete base is critical with this type of wall – do not assume it is adequate. Get advice from your supplier or a competent designer or structural engineer before installing. Trial holes or other site investigation may be necessary. See Section 2 of this guidance for more details
- Ensure walls end with 90 degree returns where possible (particularly in longer lengths of walls), this helps to buttress the walls
- On higher walls thick about using double width/spreader bottom block course to give more resistance and to spread the heavy load over a bigger area of the slab or foundation (see photograph below)

3.6 Timber sleeper and steel post walls

3.6.1 These walls are made of timber sleepers placed between the flanges of steel I beams or parallel flange channels, which are used as supporting posts. The steel posts are often cantilever from the ground but sometimes can be part of a wider building structure which means they likely won't cantilever from the base. See photograph below for an example of this type of wall.

3.6.2 The sleepers span between the steelwork which transfers the horizontal load to the foundation below. The foundation is typically supporting a cantilever post so must deal with moment loads (overturning loads) as well as horizontal and vertical loads, so often have to be quite large.

3.6.3 This type of wall is very different to the other options - the failure modes differ as well. The most common failures seen in this type of wall system are shearing of the sleepers from accidental impact force or panels becoming dislodged due to movement of the sleepers between the posts. Both can result in whole panels or a series of panels falling as they are stacked one above another, but as these are usually contained by the steelwork, this isn't typically an issue. Bearing capacity failure is still possible but this would be to the building structure or the cantilever posts foundation.

3.6.4 The positive features of the timber sleeper walls are as follows:

- Cheap to build and quick to install once the foundations are cast
- Timber sections can be replaced easily
- Useful when you don't have a slab to support a freestanding wall
- Good in internal and external conditions (although steel posts will corrode over time externally, particularly when any surface treatment is worn away by and scraping against)
- Take up small footprint, leaving move space for operations
- Can easily be extended higher (if supporting frame can allow it and the extra load it will attract)

3.6.5 The negative features of the timber sleeper walls are as follows:

- Not very robust, sleepers often wear away or break under impact loading
- Steel posts can corrode quickly in harsh environments and when exposed to scraping up
- Focuses load on post foundations which can be overloaded if ground conditions are variable
- Will not provide 2-hour fire resistance between bays and will need to be considered as a fuel source in the event of fire
- Front end shovels can snag the timber sleepers when scraping up causing them to become dislodged (see photograph below)

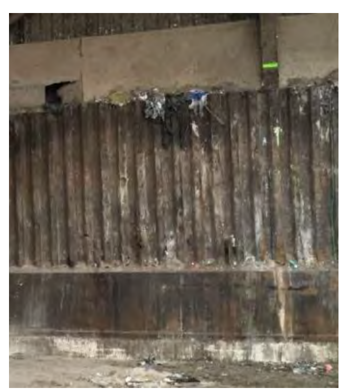
3.6.6 Some best practice ideas for the design of timber sleeper walls are as follows:

- Don't extend steel posts above height of sleepers so height of the wall cannot be increased on site
- Install steel ties or cross bracing to the steelwork to prevent steel moving allowing the timbers to fall out

Above – photograph of damaged sleeper wall

3.7 Steel plate and supporting frame walls

3.7.1 These walls are typically found in material recycling facilities under process equipment and picking bays. Often, they are used to form 3 sided bays and support the structure or equipment above. They can also be found on the perimeter of the building spanning between the steel frame of the building. The walls don't usually have their own foundation but use the slab or the building frame for support. Typically, steel walls on the perimeter of the building have an in-situ reinforced concrete section at the bottom to deal with the impact loading which is usually concentrated to this area. The walls themselves are typically a steel frame of horizontal and vertical sections with a plate welded to the frame to create the face of the wall. See photographs below of typical steel walls.



3.7.2 The horizontal load is transferred to the slab through the 3-sided structure which is created by the steel walls or using props at the bottom of the wall to the slab or a foundation below. If the steel wall spans to the steel structure it transfers the load to the main building structure and use their foundations to dissipate the load to the ground below.

3.7.3 Typically, these walls fail locally as the steel plates are damaged or corrode from the harsh environment. It is also possible that the bolts fail or come loose from overloading and vibration respectively. The wall panels can also be bent at joints and puncture from high point loads. They can also fail in more traditional ways with shear at the base and toppling at the base. See photograph below showing a damaged steel wall showing puncture damage and large deflection of the plates.

3.7.4 The positive features of the steel plate and supporting frame walls are as follows:

- Quick to install
- No need for independent foundations, depending on design conditions and suitability of the slab and structure
- Take up small footprint, leaving move space for operations

3.7.5 The negative features of the steel plate and supporting frame walls are as follows:

- Not suitable for external environments as steel likely to corrode
- Not very robust as thin steel plate makes up the majority of the wall surface

- Unlikely to last long (approx. 10 years) due to the harsh environment
- Repair will require specialist input from a fabricator
- Inflexible in terms of repositioning and adjusting bay sizes
- Not suitable as a 2-hour fire wall as per requirements of the EA Fire Prevention Plan Guidance

3.7.6 Typical issues for steel plate and supporting frame walls are as follows:

- Puncture holes in plate due to impact load
- Excessive deflection and bending of the steel plates between the supporting frame
- Corrosion of steel due to wear of protective coating and harsh environment

3.7.7 Some best practice ideas for the design of steel plate walls are as follows:

- Consider reinforced concrete dwarf walls at the bottom of the wall to prevent accidental impact loading causing the steel wall to be damaged

3.8 Best practice for all wall types

3.8.1 Typical best practice ideas for all wall types include:

- Paint on fill lines to show maximum height permitted to reduce risk of overloading, it might also discourage future manipulation of the walls and highlight if wall blocks have been moved
- Paint the end of the walls which will be exposed to operational vehicles movements to highlight their presence and reduce chance of them being struck
- Install spill plate between perimeter walls and the cladding to prevent waste getting between the walls and the cladding below the top of wall level

4. Design and construction waste bay walls

4.1 Design - appointing a competent designer

4.1.1 Requirements for appointing a competent designer are set out in the Construction (Design and Management) Regulation 2015. Any operator having a wall constructed should seek to appoint a competent designer as soon as possible in the project.

4.2 Design - proprietary wall systems design

4.2.1 Often suppliers of walling systems (such as interlocking block and freestanding precast concrete walls) will provide generic design information for their walls. This information is often heavily caveated and makes assumptions which need to be verified for the application being considered. The information is also typically limited to the design of the wall itself and not the slab/foundation and ground which supports the wall.

4.2.2 This should be used as a guide only to inform the client/operator what type of systems may be suitable for their requirements and does not constitute a suitable design by a competent designer on its own.

4.3 Design - outline design considerations

4.3.1 The client (the company who operate the facility) and the designer need to consider numerous factors when planning the design of a waste management facility and positioning the waste bay walls.

4.3.2 Typically, the edges of the building will be finished with a walling system to contain the waste pile inside the building and protect the building structure from the operation and the aggressive environment in the waste pile. Then internal walls will be positioned to segregate different waste streams or to create separate bays for fire segregation and/or operational needs (depositing bays, contractual needs, etc).

4.3.3 The positioning of the waste bay walls needs to consider many factors including, but not limited to, the following:

- Pedestrian access and escape arrangements – typically waste bay areas are non-pedestrian zones which are only accessed on foot for inspection but alongside the waste bays may be pedestrian routes for operatives (to access equipment or picking lines) and/or there may be an escape route in case of a fire. Keeping walls a distance from these routes may be necessary to prevent waste spills over the walls from encroaching in these routes or falling onto pedestrians. Where possible fire escape routes and doors shouldn't be blocked by walls unless it can be proven that suitable fire escape distances can be maintained, as per the requirements of building regulations
- Internal column positions – Walls typically need to be positioned to avoid these, but the ends of dividing walls can often line up with these so that the internal column isn't exposed in front of a waste pile, increasing its chances of being impacted. Note that if columns are exposed, they should be protected and made to stand out to alert driver and operators to their presence
- Existing or proposed fire suppression systems – walls need to account for coverage of the fire suppression systems and any blind spots they might cause to the detection system
- The existing slab levels and slopes may also dictate the positioning of walls as some freestanding walls can only be placed on slabs which are level or with a shallow slope
- The existing or proposed drainage (especially externally) may dictate where walls can be placed. Waste piles tend to need to be away from drainage surface features as they cause them to block up with waste and/or become damaged by wear and impact from the vehicles operating in the waste piles. The walls may also guide the leachate or surface water to a particular drainage point which maybe a requirement for the facility's permit.
- Walls also need to be positioned to allow the waste pile to be the right size for the operator and this can depend on a lot of factors, including
    - Number of day's storage requirement. The number of day's storage requirement should be agreed with the client and should be calculated based on the yearly throughput and the number of delivery days for that material per year. This usually allows then for seasonal variations, breakdown in equipment (plant or process equipment), problems with offtaker facilities (such as EfW shutdowns), problems with offtaker vehicles, etc. The number of days is an operational requirement and can be varied based on operator's judgement
    - Minimum of 1 full off-taker vehicle load of waste in the bay, preventing inefficient part loads
    - Suitable size waste bay for the vehicles depositing and mobile plant using the bay. This can typically be an issue on busy facilities with depositing vehicles arriving at similar times and having turnaround times (typically refuse collection vehicles). Safe distances need to be maintained between vehicles and safe operating spaces required for plant

4.4 Design - waste volume in bays calculations and waste density

4.4.1 When designing the bay, typically, a volume of waste that needs to be held in the bay is calculated (such as to provide the number of days storage required or for the offtaker load). This should be worked out using waste densities and the shape of the waste bay including the sloped working faces (which can vary in slope based on the materials ability to stand at a certain slope over short periods).

4.4.2 The density of a waste stream is important to the design of the waste pile size and the design of the walls, as it affects the loading from the wedge of waste pressing against the wall. The density can vary widely within a category of waste based on lots of factors including, how it is collected (kerbside or from a recycling centre, for example), how it has been treated (shred or compacted), what other waste streams segregated out at source (i.e. municipal solid waste, MSW, with food waste segregated is generally less dense than MSW with food waste), etc.

4.4.3 Note that using a lower density will be conservative for the waste pile size calculations and using a higher density will be more conservative when designing the walls and calculating the forces on the walls. It should be noted that some waste types, densities change over time so this should be carefully considered for waste bays which are likely to hold waste for longer periods (weeks and months, rather than days) and in large waste piles the waste at the bottom of the waste bay can be denser than the waste at the top of the bay, due to self-compaction.

4.4.4 The walls need to allow for any freeboard requirements which may be required by insurers or as per the requirements of the Fire Prevention Plan Guidance.

4.5 Design - detail design guidance

4.5.1 The first key to producing a suitable design is to determine the design parameters for the calculations. These should be decided by the operator and the designer. Parameters include:

- **The density of the waste.** Note that external conditions can cause waste density to increase
- **The angle of internal friction or angle of repose.** This is a parameter which is usually conservatively estimated rather than a known figure. Most soil types are between 25 and 35 degrees, and this gives the typical 30 degrees used for waste. Some waste streams such as mixed dry recyclates and glass bottles would probably not stand at this angle for long so a more conservative 25 degrees would be better to use whereas some materials, such as MSW, will stand at steeper angles (approx. 40 degrees). Materials stored externally should use a lower angle of repose due to moisture typically making the material less stable. Single size materials (shredded waste, glass bottles, for example) also should use low angles of repose

- **Height the waste is to be stored at.** Freeboard maybe required above this, but the walls should be checked for, at least, a level load at the top of the wall level
- **Angle of waste at the top of the pile**, which causes surcharging against the wall, as it increases the size of the wedge of waste pressuring the wall
- **Aggressiveness of the environment the wall will be subject to** a) from the waste (typically worse when retaining organic waste streams such as green waste and food waste due to acidic nature of the leachate) and b) physical wear caused by plant and machinery
- **Type of plant vehicle to be used in the bay** (including details of its weight). This is used to check the wall against accidental impact loads from the vehicle. Typically, this check assumes a level of deformation of the wall and the vehicle, the impact being at low level and the speed being very slow. It should be noted that the impact of a 20t front loader travelling at 1m/s (2.2mph) and deforming 100mm on impact is an equivalent force to a car hitting the wall at 15mph (assuming 0.4m deformation in the car). The speed of the vehicle has a big impact on the force imposed on the walls as the velocity is squared in the calculation to determine the force. This calculation should be carried out by a suitably qualified and competent Structural or Civil Engineer
- **The form of waste which is stored in the bay** (baled or loose). Note that if it is baled the stack will typically not load the wall as it should be stacked in a pyramid shape but walls should be checked for collapse of a bottom bale leading to bales falling into the wall
- **Need for the wall to provide fire resistance** (2-hour fire resistance for Fire Prevention Plan Guidance. May also be required as part of insurer's requirements and/or for building regulations)

4.5.2 All these factors should be agreed between the designer and the client and be recorded in a suitable document, such as a 'basis of design' document.

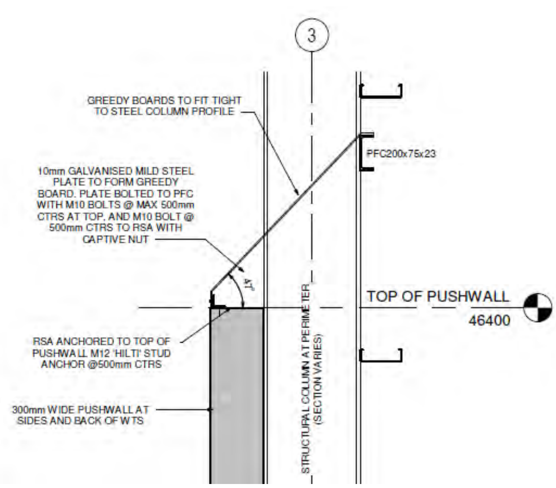
4.5.3 If the facility has several different waste streams with different densities and angles of repose it might be worthwhile designing all walls for the worse conditions to enable stock rotation and changes in use of bays. If this is not practicable, the risk needs to be highlighted to the operator, by the designer. Provide signage or to mark-up walls to highlight this risk and the wall limitations (i.e. sign saying this waste bay is for a certain type of waste only or spray painting the walls with 'MSW only' or other operational warnings).

4.5.4 The designer should carry out the typical retaining wall calculations and accidental loading calculations to work out the forces on the walls and then check the structural elements can transmit these loads to the ground with the appropriate factors of safety and set out in the applicable British Standards. The designer should also check the suitability of the ground to resist these loads without excessive settlement or movement.

4.5.5 Specific best practice examples have been provided in an earlier section of this document but below are some common best practice examples for all wall types:

- On building perimeter walls finish the cladding at top of the wall level so that there isn't a cavity between the wall and the cladding to prevent waste build up in this area. Always use robust spill plates to prevent cladding from escaping behind walls into inaccessible cavities
- Paint freeboard lines and max fill lines on walls so that walls aren't overloaded, and the fire spread freeboard is maintained
- Paint waste bays walls with name of the waste type they are designed to retain
- Paint warning signs on walls reminding operators that they are not to be driven into, scraped up and/or pushed against
- Paint ends of dividing walls which stick out into the building with black and yellow hazards stripes or finishes with steel plates finished in the same style (proprietary for some types of freestanding precast walls)
- Add wear plates to walls likely to experience operational wear through front loader operations and through certain waste types (glass, metals, etc)

4.5.6 Spill plates typically span between the top of the wall and the main building structure (typically a steel channel on the same line as the building cladding rails). The plate should be mounted at an angle to prevent waste holding above the wall (typically >40 degrees from horizontal). Spill plates in existing facilities can be made from steel plates, steel cladding or occasionally timber. Steel plates are typically used in new facilities to give the strength required to span the gap. Spill plates need to be cut tight around any steelwork to prevent any gaps which could allow waste to escape. See below diagram a typical section through a spill plate. If there are gaps in the spill plate or the spill plates fail there is potential for waste to accumulate in the cavity between the wall and the cladding/fabric of the building, see photograph below.



4.5.7 When the wall that makes up the waste bay also supports a structure above (such as a canopy, the main building structure, process equipment and/or a picking cabin) the designer needs to carry out suitable checks to prevent disproportionate collapse. In this situation, the wall used must be carefully considered to ensure it is robust enough to support the structure above as well as resisting the forces of the retained material and any accidental impact loads.

4.6 Construction – appointing a competent contractor

4.6.1 As part of the requirements under the CDM Regulations the Client needs to ensure the Contractor they appoint to carry out any works is competent. The competence of the contractor is typically accessed as part of a pre-qualification exercise before a contractor is allowed to tender for the work. The competency check will typically assess the following:

- The company's health and safety policy
- The company's accreditations (such as ISO 9001)
- The company's environmental, quality and sustainability policy
- Qualifications and experience of key staff who will be working on the project
- Examples of health and safety documents produced for other projects (such as RAMS, construction phase plan, inductions, traffic management plans, etc
- References from past projects of similar nature
- Examples of coordination and communication on past projects (meeting minutes, RFI logs, etc)
- Examples of welfare facilities provided on projects
- Examples of quality standards, H&S reviews and accident records
- Competency check policy for sub-contractors
- Financial checks

4.7 Construction – health and safety considerations wall construction

4.7.1 The different types of walls discussed in this document above have different health and safety considerations during construction. Some of these considerations are listed below for the different wall types:

- Working on operational waste facilities (for all walls):
    - Weil's disease due to high likelihood of rats on site
    - Safe access to the working area for the construction staff (due to vehicle movements)
    - Segregation of the works area from the operational areas with suitable boundary segregations (temporary walls, fencing, signage etc)
    - Trip hazards if the site is not properly cleared

    - Debris and waste on hardstanding which might get stuck under any freestanding units
    - Traffic management and control on to and around site
    - Offloading of articulated vehicles including laydown area
    - Emergency arrangements amendments
- In-situ RC walls:
    - COSHH issues with pouring concrete
    - Lifting in formwork
    - Temporary works around retaining formwork while concrete is being poured and setting
    - Working at height at the top of the formwork for the wall
    - Excavations for the foundations
    - Manual handling of steel works
    - Cuts / minor injuries from ties, bars etc
- Freestanding/bolt down precast walls:
    - Lifting the units into position
    - COSHH issues with chemical anchor bolts
    - Vibration if drilling into the existing slab
    - Dust generation
    - Confined space (depending on type of wall and installation requirements)
- Horizontal prestressed precast panel walls:
    - Lifting the panels into place
    - Working at height to fix the panels in place
- Vertical prestressed precast walls:
    - Lifting the panels into place
    - Temporary works around retaining the walls while the foundation concrete is being poured and setting
    - Excavations for the foundations
- Interlocking mass concrete block walls:
    - Lifting the units into place
    - Working at height (to set blocks in place)
- Timber sleepers and steel post walls:
    - Lifting the posts and sleepers into place
    - Excavations for the foundations
- Steel plate and steel frame walls:
    - Hot works for grinding and welding panels on site
    - Working at height to assemble the walls
    - Lifting the frame and panels into place
    - Manual handling
    - Vibration if drilling into the existing slab for fixings

4.8 Construction – client's duties and preparing for construction works

4.8.1 As the works to construct a Containment Wall will fall under the requirements of the CDM Regulations the Client's duties are clearly defined by this but some specific considerations for this type of project are:

- Clearing the area of the works from waste and debris to create a clear surface
- Segregation of the works area and the operational area
- Safe access to the works area
- Suitable welfare facilities
- Allowing sufficient time to carry out he works even if this means disrupting operations
- Providing suitable and sufficient Pre-Commencement Information
- Performing prestart and regular checks / audits on the contractor and works throughout

4.9 Construction – quality assurance

4.9.1 The contractor should have a specific QA plan for the project which will differ depending on the type of walls being installed. The QA measures may include the following:

- Concrete mix designs
- In-situ concrete QA measures such as cube tests to prove the strength of the set concrete, batching plant certificates, pre pour check sheets, slump tests, temperature checks, rebar strength certificates, reinforcement fixing checks, temporary works information, etc
- Precast concrete certificate of conformance
- LOLER certificates for lifting eyes left in precast units
- Inspection of any fire protection measures (e.g. joints filled with intumescent compounds) to the relevant specification
- Ensuring proprietary units are installed to the supplier's recommendations and guidelines
- Setting out checks (including formation levels)
- CBR testing / ground loading checks
- Pre-lay floor checks (to ensure flat, level suitable)
- Waste Transfer licences
- Pre-use and ongoing works checks (Scaffolding checks, LOLOR certs for lifting equipment, HAVS, etc)
- As-builts surveys
- Inspection of any fire protection measures (e.g. joints filled with intumescent compounds) to the relevant specification

4.10 Construction – health and safety file requirements

4.10.1 The Health and Safety File for the facility should be created by collating documents throughout its construction and should be altered as and when works are carried out to repair or alter the facility. The Health and Safety File requirements are defined in the CDM Regulations but specific information relating to projects involving containment walls should include:

- As built drawings showing the final layout of the walls and types of walls used
- Certification for the precast concrete wall elements used including safe lifting weights of any lifting eyes left in the precast elements
- Specification sheets for products used, such as well units, holding down bolts,
- QA information mentioned above
- Designers risk assessments
- Photos from construction
- COSHH information about substances and products used
- Operations and maintenance manuals for the walls
- Details of any operational limitations of the walls (max waste stack height, types of waste expected to be used, impact load limitations, plant limitations)
- Details of any unexpected conditions found during construction or details of any considerations a competent contractor may not be able to identify in the future
- Details of decommissioning procedure and requirements
- used, impact load limitations, plant limitations)

Comment – please note this is not part of formal guidance and is for information only.
While CDM allows contractors and designers to only supply the health and safety file once the construction project is completed, historically there have been example of files not being supplied as a result of financial failure and/or failure to supply the file post completion (as they lose interest, and the client loses leverage). It can be wise to insist (perhaps as a condition of progress payments or similar) that the health and safety file is produced at regular intervals during the project, and that it is shown to be up to date. Clients may want to remember that once a project is complete it can be next to, or actually impossible, to recover the design and ‘as built’ documents that will be essential for maintenance and repair of the structure over its lifetime.

5. Operational considerations

5.1 Suitability of plant

5.1.1 The common types of mobile plant used in facilities with containment walls in the waste and recycling sector are those that push against waste piles (loading shovel – as shown in photograph left below - telehandler or other with buckets) or those that pick/grab from piles (360 materials handler – as shown below right - or similar with selector grab or orange peel grab). The combination of wall type and plant used should be considered in the site risk assessment for the plant or activity (depending on how you group the scope of your risk assessments).

5.1.2 Any changes made to either the plant used or its configuration i.e. attachments and how these are used may have a detrimental effect on plant suitability for use with specific wall types and should be carefully risk assessed.

5.1.3 The plant type must be suitable for the type of wall and vice versa. The difference between a static 360 “picking and placing” waste and a loading shovel “pushing against a wall” must be appreciated. The forces applied to the walls from the two types of activity is a significant factor when selecting plant for use with walls or walls to match existing plant (plus the material being stored and handled as a design consideration) e.g. an interlocking precast concrete block system may not be the best type of wall for a shovel to be pushing against as the bucket can catch the joints if it is raised against the wall and possibly tip higher blocks off the wall.

5.1.4 If the type of waste stored changes, you should consider whether walls are still suitable and record this in your risk assessment e.g. a wall designed for light material possibly with a 360 “picking and placing”, then changes to heavier / denser material and / or a loading shovel “pushing against a wall”.

5.1.5 The selection for handling a 'material' should follow correct machine, correct type of bucket and correct size of bucket.

5.1.6 There are concerns that companies choose to use a larger bucket on a loading shovel because a material is low density i.e. bulky but relatively light e.g. woodchip. This leads to restricted operator visibility both in relation to pedestrians (general workplace transport issue) and when pushing against piles / walls as the operator may hit the wall with the bucket, increasing the risk of damage.

5.1.7 If a bucket is increased in size, then the risk assessment must be reviewed to determine whether the new combination of plant, bucket, wall, materials is still suitable; possibly leading to reverting to the previous bucket. Also filling the bucket so that it is level or heaped i.e. trying to get maximum in bucket. It is normal practice to pick up a heaped load, however the material, bucket size related to plant size and facility layout must be assessed holistically. An attempt to speed up processes such as loading vehicles with a material should not lead to poor operator practices (see 'Training and awareness of operatives' section). A Safe System of Work (method statement, procedure etc) should be written following assessment to include a step-by-step procedure detailing operation of specific plant with specific walls.

5.1.8 Vehicle and plant segregation is part of workplace transport in terms of avoiding injury to people, however managing appropriate plant and vehicles in specific areas on site will help avoid damage to walls on site. Walls can get damaged from plant moving around site whilst not pushing up or picking in a bay i.e. stabilising legs or buckets catching walls.

5.1.9 If changes are made to the mobile plant used with the push walls, then the design and other considerations in this document should be considered.

5.1.10 In documentation operators should set out and observe the hierarchy that physical improvement including the structures, facility layout and segregation must be considered before documents, training, and PPE etc. It is not adequate to resolve risks by simply jumping to training alone. Operator competence must also be addressed to ensure that operators are competent to undertake the activities expected of them. Competence goes beyond just training and should include assessment of performance in practice (often through supervision).

5.2 Operation of plant

5.2.1 Following selection of suitable plant, correct operation must be managed. If walls are designed for "picking and placing" of material or "pushing against", the specified plant must continue to be used. The consequences of changing type of plant may include dislodging or pushing over component blocks or panels.

5.2.2 Use of the back wall as a lever is to be avoided, material is picked up as described in the first paragraph of the 'Training and awareness of operatives' section below. The bucket should not be driven into a wall, the material should be picked up in a manner as if the wall is not there. Avoiding contact with the wall becomes more difficult as the pile becomes smaller and / or operators are trying to completely clear a bay / area, see photograph below of wear resulting in reinforcement being exposed.

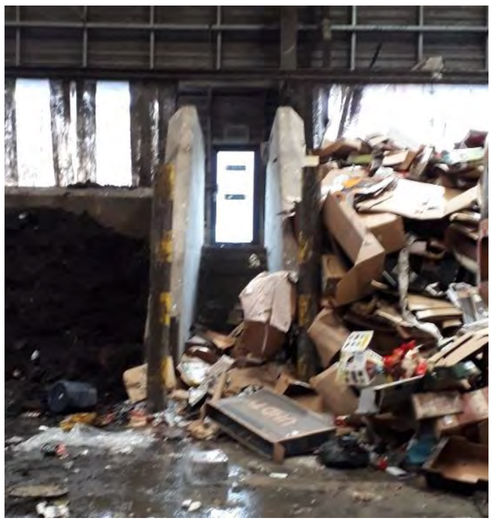
5.2.3 If the walls are intended as dividing walls for the waste and not to be pushed against, this must be clear, and piles picked from using appropriate plant. Operators must be instructed of the intended method of use.

5.2.4 All organisations experience some level of bay wall damage as a result of plant interaction / contact - frequently emptied bays will suffer the most. The frequency and level of damage will need to be monitored and assessed as to whether it is wear and tear or significant damage. If an operator is repeatedly causing damage, then greater observation or retraining / reassessment will be required. Investigation may also identify a mismatch of plant and task as well as operator skill or poor decision making.

5.2.5 The cumulative damage such as chunks missing, and scrapes result from of years of use and require monitoring - see the 'Inspection considerations' section. Inappropriate plant can result in damage to the plant as well as walls adding to repair costs.

5.2.6 Consider plant used near walls that also create walkways. Vehicle and pedestrian interaction must be avoided where possible - keep pedestrians out of plant operating areas generally and segregated in areas with vehicle and pedestrian routes (management of workplace transport). If, for example, wall structures also form walkways including emergency escape routes, then managing the hazards from the plant use such as material being pushed or picked coming over the walls must be considered.

5.2.7 The strength of the wall and the fact that it is loaded on one side only, especially with a pedestrian route must be factored into the design. Control of pedestrians using the route, preferably in an emergency only rather than regularly must be monitored and managed. If pedestrian routes are used regularly then consider controls such as lights and sounders to manage access to a route beside a wall, which corresponds with the plant activity. This risk of impact may determine that alternate pedestrian routes need to be planned and used. There are other considerations, such as blocking of escape routes, such as shown in the photograph below of wastes blocking a fire escape route.



5.2.8 Also, vehicle routes adjacent to walls are to be considered in terms of possible damage to those vehicles from again, material being pushed or dropped over the walls. Vehicle routes adjacent to walls are common, however; all plant, vehicles, materials, proximity of activities are to be included in risk assessment of site activities, as are the risks to pedestrians on the site.

5.2.9 All of those selections must be communicated to staff, contractors, and visitors by way of the appropriate method for each group of people and their activities e.g. training, briefing, induction, site rules, signage, etc.

5.2.10 Further to that information, and prior to starting work or accessing site, good communication across a site is necessary to ensure plant operators, pedestrians, and drivers (own and visitors) follow the risk assessments, site rules, traffic management etc. including use of the permitted routes and areas. Use of radios is widespread so that once beyond the site reception / weighbridge further instructions can be given if a situation changes e.g. breakdown of a vehicle or a driver not following the original instructions given.

5.3 Training and awareness of operatives

5.3.1 Safe driving is critical to minimising damage to walls and machinery alike. Think carefully about who you select as a plant operator, train them and assess their competence on an ongoing basis. This should cover site rules and procedures as well as the correct methods of using the mobile plant including travelling at a low speed and with the bucket low for as long as possible (but not on the ground/slab) and using smooth rather than jerky movements or rapid changes of direction.

5.3.2 Front end loaders with a bucket are pushed into the pile low down and with the bucket horizontal to the floor, then lifted and curled as picking up the material so that maximum volume is picked up; there is no need to drive at the pile at speed, leading to spinning wheels or even lifting rear wheels because the bucket is driven too deeply into the material. Operating plant correctly reduces the risk of accidents involving pedestrians and damage to plant or walls as well as fuel efficiency (environmental and economic benefits).

5.3.3 Operator behaviour will be influenced by many factors, including personality, pressure (perceived or real) to work quickly, their initial and refresher training, organisation culture and priorities. All organisations, regardless of how they train, risk assess, provide suitable plant etc. must promote good operator behaviour and undertake monitoring to ensure operators are operating plant as trained and expected, as well as client drivers and customers behaving on site as expected. The good practices must be acknowledged as part of ensuring they continue.

5.3.4 Sites need to thoroughly assess workplace transport risks & devise site rules covering best practice for driving and emptying bays. The rules must be consistently enforced – this is a key role of site managers and supervisors, and they should be supported in this. Failure to challenge poor driving practice is a major factor in ensuring future non-compliance.

5.3.5 Safe driving minimises damage to plant as well as walls. Poor practice such as driving at speed into piles, with the bucket too high, pushing against walls too high or using a grab with a lack of control can be picked up by monitoring or near-miss reporting by others. Operators intentionally trying to damage plant and walls may be an issue if disgruntled and should be managed as any disciplinary issue.

5.3.6 Operators must be made aware of the nature of damage that can be caused by the plant types and activity. Whether "pushing" with shovel leading to the low-level damage from constant impacts from or breaking a wall from the horizontal impact; or "picking and placing" causing higher level damage from a 360, catching walls with the plant or attachments or the material it is moving.

5.3.7 The different types of plant and the associated hazards and risk are generally covered in training in terms of possible harm to people. If not already, consider inclusion of the structural capability (having knowledge of the design and specification of newer walls or having inherited / older walls surveyed) of the walls and the possible damage to infrastructure in your training. Operators must think about the load and damage they can do by pushing buckets into walls or compressing the material against a wall.

5.3.8 As with using over-sized buckets, operator practices of over-filling the bucket to reduce the number of movements can lead to damage to walls due to the related reduction of visibility or simply rushing. If there are rear walls and dividing walls i.e. a distinction that requires different use - whether you can push into a pile or whether it must be picked from only - is detail that needs to be communicated to operators by inclusion in and training of the Safe System of Work.

5.3.9 All organisations should encourage accident, damage and near-miss reporting as part of a good safety culture. Operators must be encouraged to report defects that they spot as well as damage as this occurs (it may be more likely for them to report the defects rather than damage). See the following 'Incident reporting and defect reporting' section.

5.3.10 Any unreported damage should get picked up by the monitoring of the wall condition (equally operator pre-use and manager inspections of plant will pick up damage to plant). Consider the type of plant, wall and activity when determining the need for and frequency of any inspection. Often areas of wall are covered therefore damage is not visible, effort needs to be made to inspect walls when bays are empty as well as at set regular dates. Further information follows in the 'Incident reporting and defect reporting' section.

5.4 Incident and defect reporting

5.4.1 The purpose of reporting incidents involving damage to walls and defects found at other times is to ensure walls remain in a condition that does not lead to structural failure such as collapse and to ensure they are maintained in safe working order.

5.4.2 Wall damage and defects can be picked up by several types of reporting, however it is worth noting that it is more likely with simpler methods, and a positive safety culture that leads to greater reporting, rather than where there is an expectation of blame or punishment if damage is caused.

5.4.3 As the previous section, plant operators are expected to report any damage that they cause because of striking walls with plant buckets and grabs or parts such as legs when moving plant to or from a picking / loading position. Damage may also be caused by other types of vehicles such as those used for bringing materials to site or taking materials from site. Again, reporting by employees or visiting drivers is to be encouraged.

5.4.4 These damage incidents should be reported immediately enabling a quick assessment by operational managers or more detailed inspection by member of an in-house engineering team or an external competent person or, as necessary. Initial reporting can be made verbally, followed up with a record form completed to enable details to be captured and procedures to be followed. An all-inclusive incident form can cover damage as well as injury and near misses, keeping these forms in plant and vehicle cabs enables prompt completion by the operatives and drivers.

5.4.5 Defect reporting can arise from a variety of methods or occasions. Operators may spot damage not immediately caused by themselves but perhaps since their last day working in the same area. Supervisory staff may complete a site, asset, structure inspection and find defects. Site tours by managers, directors or visiting support staff such as engineering, plant trainers, H&S etc. may be that fresh set of eyes that spot damage not seen by site staff due to familiarity with their surroundings.

5.4.6 Sections of walls may not be visible for periods of time due to pile sizes, therefore opportunity to make unplanned / unscheduled inspections must be taken. Ideally, waste piles are rotated to empty bays / clear walls to enable regular inspection.

6. Inspection, maintenance, and modifications

6.1 Inspection frequency and scope

6.1.1 When building new containment walls or ensuring the safety of existing walls, it's important to have an effective inspection regime. This will help to identify damage so that mitigating steps can be taken before failure occurs.

6.1.2 To build an effective history of inspections, facilities should develop a containment wall register where all structures are identifiable either by numbering or utilising a site layout, ies the site traffic management plan. This will ensure that all structures are inspected and that any findings are aligned, between inspections, so that the appropriate remedial actions can be taken.

6.1.3 Appendix 2 provides an example wall inspection records with a marked-up site plan. Appendix 3 has an example blank inspection records for use when inspecting containment walls.

6.1.4 The frequency and scope of inspections will need to be determined by a competent person. While there will be variances between the different structure types the following should be considered:

- Does the wall appear to be sound and stable?
- Signs of cracking or wear at the base or in the main body?
- Signs of exposed reinforcing metalwork?
- Signs of movement or misalignment?
- Signs of damage to or wear to fixings, joints, bolts or support bars?
- Signs of loose or damaged base anchoring?
- Signs of overloading?
- Signs of significant impact damage?
- Signs of misuse contrary to safe procedures?
- Signs of damage to vertical structural members?
- Signs of significant corrosion deterioration?
- Signs of deterioration of ground conditions and bearing capacity?
- Inspect the slab local to freestanding walls for cracking and movement which could indicate excessive movement of the slab or ground supporting the wall
- Near miss or hazard reports submitted?
- Signs of fractured panels?
- Signs of block wall joint gaps in excess of 10mm?

- signs of block walls out of alignment or not fully bonded?
- signs of missing warning signage or barriers to prevent access to danger zones?
- Has the material being stored been changed compared to what it was originally designed for?
- Is the material being stored stacked too high (above top of wall or freeboard levels)?

6.1.5 Appendix 4 has the above checklist on a separate sheet which can be printed out and taken on site during inspections.

6.1.6 To ensure consistency across inspections specific guidance should be developed for each wall type as detailed in the design section of this guidance.

6.1.7 Written records of inspections should be made supported by photographs which will aid analysis and supporting any trending of common defects. Examples of blank and completed inspection templates can be found in the Appendix 2 and 3.

6.1.8 Inspections will typically fall into 2 areas:

1. Operational inspections conducted regularly by the site team using simple reference guides on what to look for
2. Engineering inspections conducted by a competent person who is a qualified professional (either a member of the Institution of Civil Engineers or a member of the Institution of Structural Engineers). They will determine the frequency although additional inspections will be required in the following circumstances:
    a. Following a fire within a containment wall structure
    b. Where an operational inspection has identified defects that require further structural review
    c. If significant changes in operation are planned so that the wall can be assessed before changes are made

6.1.9 Prior to any inspections the site must be clear of waste or have means to clear it if further access is needed in particular areas.

6.1.10 The aim should be for inspections to be conducted without the need to enter the bay (wherever possible). An example could be utilising CCTV or whether any elements of the inspection be conducted from the vehicle cab (where the raised position provides a different view in relative safety).

6.1.11 When pedestrian entry is required, for operational or engineering inspections (or for any operational needs), a risk assessment should be in place that details the controls that are required to be implemented. Using the risk hierarchy, the aim is to eliminate the hazard first by either avoiding the task or looking at ways to conduct it by the safest means. Controls may include the suspension of all vehicle movements, the segregation of the area by the parked mobile plant (preventing any tipping) and the use of 2-way radios between staff so that communications can be maintained at all times. Proximity warning systems can also be used (where fitted). Consideration should also be given on whether a permit to work system may be beneficial in formalising this process, particularly if a wall has failed, deteriorated or is damaged.

6.1.12 Engineering inspections are to include the following, as a minimum:

- Executive summary highlighting key issues and actions
- An introduction defining the scope of the inspection and any limitations of the inspection
- The mobile plant being used
- The wall construction
- The material being stored
- Any relevant manufacturer and / or design data
- Details of the inspection that was carried out
- Observations from the inspections with inspection sheets for the walls
- Discussion of the observations
- Conclusions and recommendations for works to be carried out and timescales for these works and when the next inspection is recommended
- Drawing of the site referencing key issues and the walls surveyed
- Photographs and measurements taken during the inspection
- Legal requirements for reference, such as
    - Construction Design and Management (CDM) Regulations 2015
    - BS6399-1:1996 Loading for Buildings

6.2 Maintenance and modifications

6.2.1 There will be times when containment walls will need to be maintained, either to make repairs or to make modifications due to a change of use or to meet revised site demands. When this occurs similar designs and construction arrangements need to be made as detailed within the construction section of this guidance:

- Any modifications or repairs need to be made in-line with manufacturer's recommendations and with the support of a competent person.
- Walls should not be fitted with non-standard extensions without a suitable assessment and sign-off by a suitably competent person
- Repairs may be instigated following a proactive inspection, either by operational teams or periodically by an engineering function
- Reactive repairs may be raised following an incident where damage has occurred, where cumulative inspections have raised an issue or following a fire where the integrity of the wall has been brought into question

6.2.2 Where modifications or repairs have been made these should be recorded and referenced back to the site containment wall register.

References

1. The Management of Health and Safety at Work Regulations 1999 (as amended)
2. The Workplace (Health, Safety and Welfare) Regulations 1992 (as amended)
3. HSG136 A guide to workplace transport safety and *WASTE 09: Safe transport in the waste management and recycling industry* WISH guidance

Disclaimer and WISH

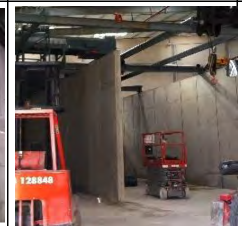
Nothing in this guidance constitutes legal or other professional advice and no warranty is given, nor liability accepted (to the fullest extent permitted under law) for any loss or damage suffered or incurred as a consequence of reliance on this guide. The guidance is not a substitute for duty holder judgment and/or professional safety advisor's judgment, Notwithstanding the good practice in this guidance, duty holders are responsible for ascertaining the sufficiency and adequacy of their internal and independent procedures for verifying and evaluating their organisation's compliance with health and safety law. WISH accepts no liability (to the fullest extent permitted under law) for any act or omission of any persons using the guidance

The Waste Industry Safety and Health (WISH) Forum exists to communicate and consult with key stakeholders, including local and national government bodies, equipment manufacturers, trade associations, professional associations and trade unions. The aim of WISH is to identify, devise and promote activities that can improve industry health and safety performance. All WISH documents are available as free downloads at https://www.wishforum.org.uk/

Further information

This guidance is issued by the Waste Industry Health and Safety (WISH) Forum to help control safety and health risks. Following the guidance is not compulsory, unless specifically stated, and you are free to take other action. But if you do follow the guidance, you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance.

Appendix 1: matrix of typical containment walls

Type of Wall	In-situ reinforced concrete	Freestanding or bolt down precast concrete	Horizontal precast concrete panel	Vertical precast concrete panels	Interlocking mass precast concrete block	Timber sleeper and steel post	Steel plate and frame
Typical Picture							
Suitability for 2-hour fire wall	Usually, subject to wall thickness and design	Possibly subject to joints being sealed*	Possibly subject to joints being sealed*	Possibly subject to joints being sealed*	Possibly subject to joints being sealed*	No	No
Resistance to impact loading	Good	OK	OK	OK	OK	Poor	Poor
Max height of wall	5m	5m	5m	5m	4.8m	5m	5m
Fixed to foundation and/or slab	Yes	Sometimes, depends on design	No (uses supporting frames and their foundation)	Yes	No	Yes (steel column needs a foundation)	Yes
Considerations	Inflexible, costly, cannot be replaced/repaired easily	Flexible, wide based can hinder operations	Reliant on steel frame for support, clamps can come loose	Inflexible, costly, cannot be replaced/ repaired easily	Flexible, robust but failure can be catastrophic	Steel posts are exposed, timbers can be replaced, inflexible	Inflexible, not robust, susceptible to corrosion

Heights of wall assumed to be max 5m as waste cannot be stored above 4m (as per Fire Prevention Plan Guidance requirements). Height achievable is subject to the situation and design

*Sealing compounds need to be of a fire resistant, intumescent type.

Appendix 2: marked-up site plan and example inspection records

Appendix 2: marked-up site plan and example inspection records

Wall Inspection Form

Site	Date	Reference on site drawing
Wilmington	12/08/2016	01

Wall Type	Push or dividing
Lego Style Concrete Blocks	Segregation/Traffic management

Wall Condition (Wear, damage, movement, fixed down, strapped together)	Wall in ok condition, some minor amounts of wear and localised damage but nothing excessive
Whole wall dimensions	0.8m high x ~40m long
Each unit dimensions	1.6m long x 0.8m wide x 0.4m high
Verticality	OK
Materials retaining	None
Foundation/bearing slab condition	External slab in ok condition.
Vehicles used on site	Front loaders, Grabs, RCV, Articulated lorries.
Other comments and observations	Blocks stacked with no horizontal bond/interlocking (i.e. a stretched bond in brickwork) so each column of concrete blocks works independently.

Take photos of the wall and foundations and elements highlighted in the above form. Sketch wall on site plan and provide reference number (see top right box)

Wall Inspection Form

Site	Date	Reference on site drawing
Wilmington	12/08/2016	02

Wall Type	Push or dividing
Lego Style Concrete Blocks	Push

Wall Condition (Wear, damage, movement, fixed down, strapped together)	Localised wear and damage in some areas. Large damaged sections on some blocks
Whole wall dimensions	1.2m high x ~40m long
Each unit dimensions	1.6m long x 0.8m wide x 0.4m high (small blocks) Some large blocks which are 0.8m high
Verticality	Leaning slightly in some areas, approx. 1 in 20 off vertical. Therefore centre of gravity is out by 3cm
Materials retaining	Fridges, bins
Foundation/bearing slab condition	External slab, unable to inspect due to material in place
Vehicles used on site	Front loaders, Grabs, RCV, Articulated lorries
Other comments and observations	Blocks stacked with no horizontal bond/interlocking (i.e. a stretched bond in brickwork) so each column of concrete blocks works independently.

Take photos of the wall and foundations and elements highlighted in the above form. Sketch wall on site plan and provide reference number (see top right box)

Appendix 3: Example blank inspection record sheet

<table>
<tr><th colspan="4">Wall Inspection Form</th></tr>
<tr><td>Site</td><td colspan="2">Date</td><td>Reference on site drawing</td></tr>
<tr><td colspan="2">Wall Type</td><td colspan="2">Push or dividing</td></tr>
<tr><td colspan="4">Wall Condition (wear, damage, movement, fixed down, strapped together)</td></tr>
<tr><td>Whole wall dimensions</td><td colspan="3"></td></tr>
<tr><td>Each unit dimensions</td><td colspan="3"></td></tr>
<tr><td>Verticality</td><td colspan="3"></td></tr>
<tr><td>Materials retaining</td><td colspan="3"></td></tr>
<tr><td>Foundation/bearing slab condition</td><td colspan="3"></td></tr>
<tr><td>Vehicles used on site</td><td colspan="3"></td></tr>
<tr><td>Other comments and observations</td><td colspan="3"></td></tr>
<tr><td colspan="4">Take photos of the wall and foundations and elements highlighted in the above form. Sketch wall on site plan and provide reference number (see top right box)</td></tr>
</table>

Appendix 4: inspection checklist

- Does the wall appear to be sound and stable?
- signs of cracking or wear at the base or in the main body?
- signs of exposed reinforcing metalwork?
- signs of movement or misalignment?
- signs of damage to or wear to fixings, joints, bolts or support bars?
- signs of loose or damaged base anchoring?
- signs of overloading?
- signs of significant impact damage?
- signs of misuse contrary to safe procedures?
- signs of damage to vertical structural members?
- signs of significant corrosion deterioration?
- signs of deterioration of ground conditions and bearing capacity?
- Inspect the slab local to freestanding walls for cracking and movement which could indicate excessive movement of the slab or ground supporting the wall
- near miss or hazard reports submitted?
- signs of fractured panels?
- signs of block wall joint gaps in excess of 10mm?
- signs of block walls out of alignment or not fully bonded?
- signs of missing warning signage or barriers to prevent access to danger zones?
- Has the material been changed compared to what it was originally designed for?
- Is the material stacked too high (above top of wall or freeboard levels)?