Applications and risks associated with a low cost flood defence barrier

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Abstract

An innovative low cost self erecting flood barrier is described (patent pending) and its applications discussed. The flood defence is provided by a geomembrane embedded in a backfilled trench and attached to rigid covers that rise with the flood waters. The covers are restrained by ties attached to the membrane.

It is considered particularly appropriate for protection against floods up to 1m in depth where a permanent defence barrier would intrude into the landscape or require the import of expensive fill material to create impermeable bunds. It is also relevant on more permeable ground where foundation cut off walls might otherwise be required to reduce ground water flow.

The risks associated with the use of such a self erecting membrane are assessed in comparison with traditional permanent walls or banks and the temporary demountable barriers employed in the Severn valley region in recent months.

It is demonstrated that the self erecting barrier is cost effective particularly where the visual amenities of a waterside area would otherwise be lost.

Keywords: flood defence, flood barrier, geosynthetic membrane, self erecting, low cost, flood risk, walkway, visual intrusion, preserved environment.

1 Introduction

Flooding is a major problem throughout the world. In England and Wales alone, around 5 million people, in 2 million properties, live in flood risk areas (ref Environment Agency [3]). Climate change will cause more extremes of weather which may increase the risk of flooding. Flood protection and flood risk mitigation is a burgeoning problem which must be addressed.

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It is considered that there is great need both in the UK and internationally for application of a low cost flood defence for the prevention of fluvial flooding and to help resist the destructive forces of storm surge and tidal flooding. Currently the demountable barriers available on the market are costly to install and maintain, are complex in their design and are not self-erecting. There have been problems where the stored demountable barrier could not be brought to site from the storage area because of the local flooding. This low cost, self erecting product is perceived to fill a gap in the current worldwide market. In addition to providing flood protection, the barrier may also be used for temporary storage of water or for protection against spills from tanks.

The Greenwood flood barrier is applicable worldwide to both small and medium sized sites. Material costs are low and installation is straightforward requiring only 'low tech' excavation equipment and manual labour under engineering supervision. This semi-permanent barrier can be installed where a permanent flood barrier scheme is not affordable, there is insufficient space or it would intrude into the visual amenities of a waterside area.

Table 1: Possible applications of the low cost self erecting flood barrier.

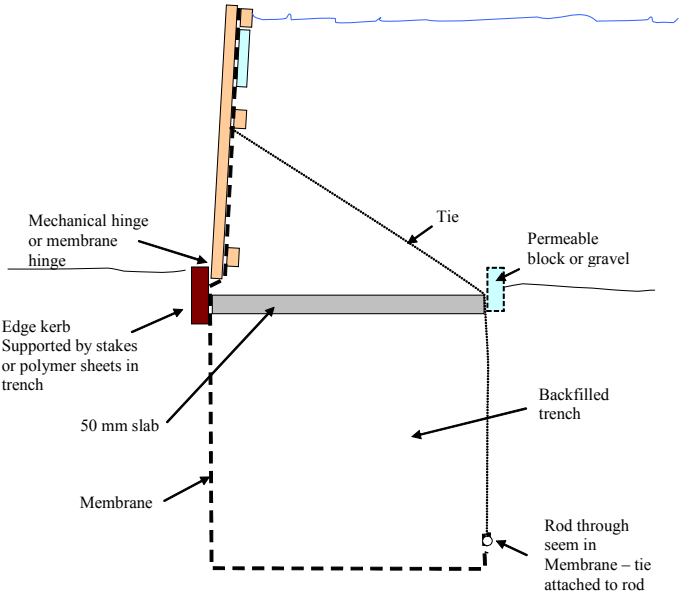
- Protection of new and existing waterside property where scenic views are to be maintained and visual intrusion of flood defences to be avoided.
- Add to the effective height of existing flood defence embankments without visual intrusion and without increasing foundation pressures (important on compressible alluvial soils)
- Temporary storage of water – farm use during dry periods, fire fighting provision etc.
- Forming a protective barrier around storage tanks of liquids which could be harmful to the local environment.
- Control of drainage/balancing pond/ soakaway waters from urban areas and highways etc.
- Coastal installations (as walkway) to resist some of the effect of a tsunami wave (with possible inclusion of shock absorber in ties)

The relatively low cost of the barrier is also likely to be attractive to developing countries where there are limited resources, inadequate flood protection and often frequent flooding. If suitably strengthened it has the potential to be used as a wave barrier designed for rapid activation in the event of a tidal wave or tsunami. Possible applications are listed in Table 1.

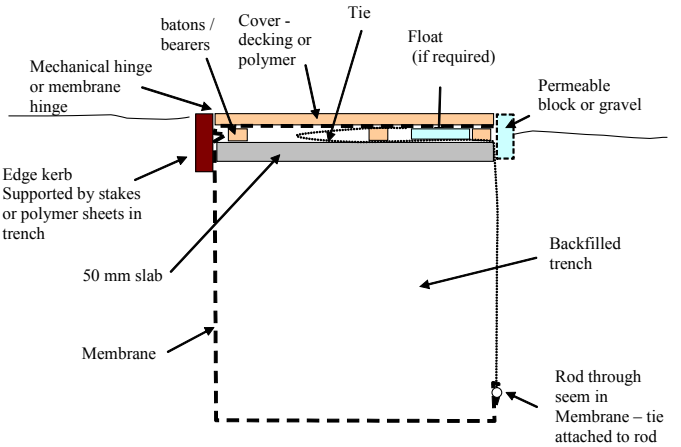
2 Description

The Flood and Wave Barrier has been developed by the lead author (Patent pending) in conjunction with Nottingham Trent University, Faber Maunsell Ltd and PAGeotechnical Ltd.

The barrier consists of a flexible impermeable membrane held in a trench as illustrated in Figure 1a and 1b. Protective rigid covers and floats (possibly incorporated in the covers) are attached so that the membrane will rise up with any flood waters and protect the land and property behind it. Stability is maintained by the mass of soil backfill replaced in the trench, slabs of concrete or other material on top of the backfill and by flexible ties, attached to the membrane (or possibly formed as an extension of the membrane), to resist the



a) The barrier self erects at time of flood.



b) The barrier at ground level when not in use.

Figure 1: The self erecting flood barrier – design features.

hydraulic forces on the erect barrier. The membrane buried in the trench also acts as a cutoff to prevent flood waters passing beneath the barrier.

When not in use the barrier will rest at or near ground level, protected by the rigid covers. The covers are hinged from a reference kerb which may be of timber, plastic or other composite materials. The hinge may be the geomembrane itself or a positive mechanical hinge depending on the particular application.

Where the barrier is to be constructed in an urban area or as a walkway or roadway, kerbs of timber, concrete or other suitable material may be placed at the edges of the backfilled trench to support more rigid covers which are able to withstand traffic loading. Alternatively a box structures, of a form similar to a polymer crate, may be placed in the trench [1] to provide stability and support the covers in the event of traffic or other loading when the barrier is not in use.

Whilst the basic barrier design principle is straightforward and the material and construction costs are likely to be low, it is important that the design details are carefully considered for efficiency of construction, safety in operation and convenience when not in use.

3 Construction sequence

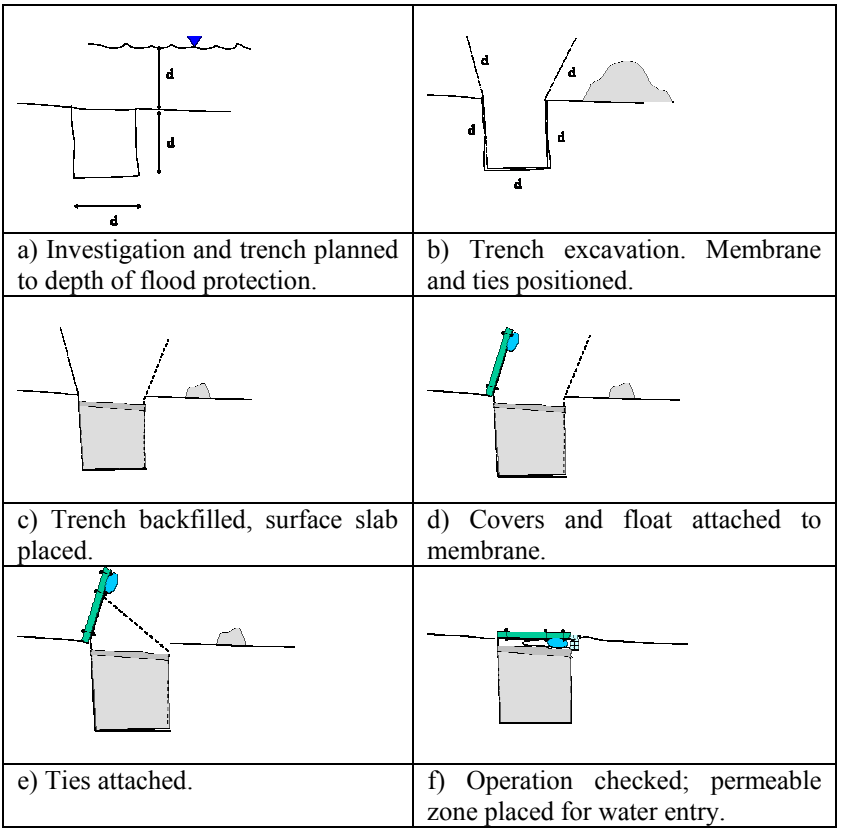
The site must be fully appraised to determine whether the low cost self erecting flood barrier is the most appropriate solution bearing in mind the funding available and the acceptable levels of risk. Suggested items to consider are listed in Table 2. The sequence of trench excavation and barrier construction is illustrated in Figure 2 (a to f).

Table 2: Pre-installation checks.

Investigation of ground and groundwater conditions
Flood risk and frequency (historic)
Depth of flood to be designed against
Environmental changes affecting flood risk
Need to maintain waterside views and minimise visual intrusion of flood defence barrier
Need to use ‘at-rest’ barrier as a walkway
Planning discussions with Environment Agency and Local Authorities

4 Pilot trials

After small scale model trials and a review of the theoretical earth pressure and water forces acting on the flood barrier structure, a full scale pilot trial was carried out in September 2007, to demonstrate the basic construction and design principles. A convenient site was made available by the Environment Agency adjacent to a lake at Lea Marston, Warwickshire. Figures 3 to 8 illustrate the various stages of construction and operation of the barrier.



a) Investigation and trench planned to depth of flood protection.

b) Trench excavation. Membrane and ties positioned.

c) Trench backfilled, surface slab placed.

d) Covers and float attached to membrane.

e) Ties attached.

f) Operation checked; permeable zone placed for water entry.

Figure 2: (a to f): Construction sequence.

Figure 3: Trench excavated, reference kerbs placed.

Figure 4: Ties attached to membrane (Seaman XR5) at base of trench.

Figure 5: Trench backfilled and paving slabs positioned.

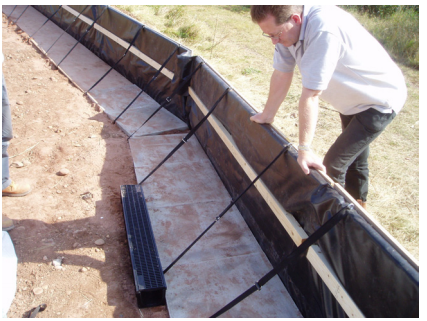


Figure 6: Membrane enclosing polystyrene float and ties attached.

Figure 7: Flood barrier at rest – ready for the flood.

Figure 8: Water pumped in to simulate the flood. The barrier rises.

The barrier successfully rose and retained 600mm depth of water. Further details and pictures of the Lea Marston trial are given in Greenwood [1] and a discussion on the membrane selection and design parameters used is given by Greenwood et al [2].

5 Benefits of the self erecting flood barrier

The suggested benefits of the low cost, self erecting flood barrier are summarised as follows:-

- Waterside views retained, minimal visual intrusion.
- Device sits unobtrusively at ground level when not in use
- Covers and kerbs designed to suit local needs – possible walkway
- Low material and installation costs
- Small amount of surplus soil to remove from site (most is used to backfill the trench)
- Installation straightforward with small excavator and compactor

- No heavy construction plant required.
- Skilled labour not required to install the barrier
- Design is flexible to cope with local ground conditions and services
- Ground membrane prevents seepage beneath the barrier
- No personnel needed for erection in flood (Good practice to observe self erection during flood)
- It is always there ready to rise in the event of a flood
- Relatively straightforward to cope with changes in horizontal direction and vertical gradient

6 Consideration of design issues

6.1 Design issues

It is recognised that the success of the proposed barrier depends on the right applications and attention to design detail. During the on-going development stages a number of issues have been considered by the project team and these are discussed as follows:-

6.1.1 Geomembrane durability

Membrane will have high resistance to UV exposure and covers will prevent exposure to light in the 'resting' position. Lifespan expected to exceed 20 years.

6.1.2 Geomembrane damage

Membrane will be high strength, high puncture resistance reinforced flexible material. Damaged sections (by accident or vandalism) may be replaced by attaching new sections by heat welding or by fixing beneath screwed batons.

6.1.3 Vandalism

The membrane would normally be protected by the horizontal covers. The string of covers and membrane will be quite heavy and not easy to lift manually. If vandalism is a real problem and flood watch personnel are always on duty, covers could be locked in horizontal position when not needed.

6.1.4 Debris strikes

The main flow will be parallel to the barrier line and direct strikes by heavy floating objects such as tree trunks would be unlikely. The biggest danger is a heavy object catching on a tie, perhaps tending to close the cover slightly if the current is strong. This risk is reduced by keeping the tie connections near the middle of the covers.

6.1.5 Post flood condition

There is likely to be considerable mud and debris collected as a result of the flood and therefore it is likely that some manual cleaning of the barrier resting slab will be necessary before the covers can return completely to the horizontal resting position. The covers, membrane and hinge systems would be checked for damage after a flood event.

6.1.6 Lifting during maintenance
The membrane will have sufficient strength that when a cover section is lifted manually, adjacent sections will rise without damage to the membrane. Temporary props can hold the covers erect during maintenance.

6.1.7 Buoyancy of covers
The buoyancy will be designed to exceed the mass of material used in the covers to ensure adequate lift during the flood. Buoyancy will be provided by separate compartments to reduce risk of problems due to puncture damage of hollow buoyancy units (hollow may also be filled with polystyrene as safeguard)

6.1.8 Hinge operation
Cover may be designed with the geomembrane acting as the hinge. The cover would ideally rest against the edge kerb in the erect position although a robust membrane could withstand the full water forces.

If a conventional hinge is used to fix the position of the cover, the materials and construction will be robust to withstand foot and vehicle traffic passage when horizontal and water forces in use. The robust hinge design will be durable and ideally be resistant to vandalism.

6.1.9 Vehicles or items on the barrier
It will be necessary for the owner of the barrier to ensure that it is not covered by an item that could prevent operation at the time of flood risk. The responsible owner would normally wish to check the barrier operation as the flood waters rise.

6.1.10 Groundwater flows beneath the barrier
The barrier is designed to restrict groundwater movement to a depth equal to the height of flood protection. This depth can be extended where investigation shows the presence of particularly permeable gravely soils. The buried membrane may modify local groundwater flow conditions and this will need to be assessed during the barrier design.

6.1.11 Liabilities
The barrier will be designed for the specific conditions predicted at a particular site, to rise and retain the specified depth of flood water and prevent horizontal ground water flow for a defined depth below the barrier. Components will be designed and tested to meet expected defined conditions. The somewhat unpredictable and uncertain nature of particular flood conditions, with water possibly entering the defended property by alternative routes (for example by drains and sewers) are such that no guarantee can be offered for complete protection based on the flood barrier alone.

It will be the responsibility of the barrier owner to ensure that it is maintained in a working condition when required to rise.

6.1.12 Planning consent
Whilst the self erecting barrier may not be as significant as a permanent flood defence wall or embankment, the need for approvals should be checked with the

Local Authority responsible and the Environment Agency. It is also possible that certain sites may need further permissions from the relevant authorities where sites are important for the environment, conservation or archaeological value Environment Agency [4].

7 Conclusions

The self erecting flood barrier has various applications and is particularly appropriate as a low cost alternative to the demountable barriers currently employed where waterside views and access to amenities are to be preserved. The single modest, one-off installation cost offers considerable saving compared with the high purchase, storage, erection and dismantling costs of the demountable barriers.

Successful initial trials of the prototype version at the Environment Agency Site at Lea Marston have confirmed the viability of the design and the project team is continuing to work with interested clients to develop systems for pilot commercial installations.

It is considered that the low cost, self erecting barrier is, in line with Environment Agency guidance [3], by offering innovative use of technology to improve the ability to cope with floods and to deliver optimum environmental benefits.

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