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FLOOD RESILIENCE TECHNOLOGY AS A TOOL OF ADAPTATION OF THE BUILT ENVIRONMENT TO INCREASED FLOOD HAZARD AND RISK

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ABSTRACT

The built environment is already exposed to the risk of flood damage. The risk is increasing due to climate change, the increased land use, the increased value of property in the flood prone areas. Technology provides the means for limiting the flood damage by adopting the policy of "living with the floods". Barriers are erected at property level, prior to the rise of flood level above the damage threshold of that particular property. Flood resilience (FRe) technology is already available and there is scope for more products, more designers, more manufacturers to enter this growing market and contribute towards the reduction of flood damage and loss of life due to flooding. A design tool and a prototype flood barrier were developed during the FP7 EU funded project SMARTeST which enables the road to market of flood resilient technology. The design tool and the prototype are presented in this paper.

1 INTRODUCTION

Storm water management may be divided into four stages:

1. Collect and re-use at source – Rain Water Harvesting.
   Water is an asset and not a threat. Every effort must be made to collect it at source and use it at property level. Water escaping the property is a loss of assets and a burden to society. The approach of directing the water away from the property instead of collecting it is still widely used (figure 1). This is not sustainable regarding water use and it increases the risk of flooding downstream.

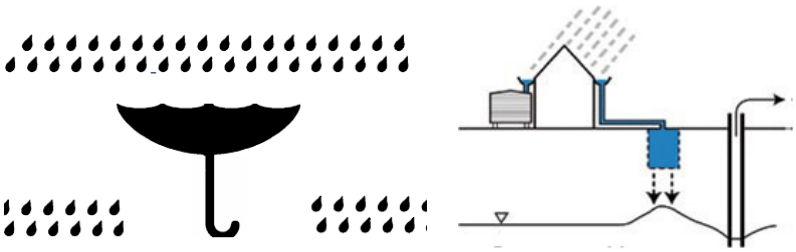


Figure 1. Collect and re-use water at source. Turn the umbrella upside-down. (http://www.un-igrac.org/)

2. Delay run-off/ reduce flow rate: SUDS - Sustainable Urban Drainage Systems.
   The excess water that may not be kept at property level drains to the public property. The aim is to delay the run-off and reduce the flow rate as much as possible. Such measures include the use of retention ponds, permeable pavements, absorption pits and ditches. SUDS are increasing used and the trend is encouraging.

3. Collect and transport run-off to rivers, lakes, sea.
   The third stage is the collection of storm water and its transportation to receptors such as rivers, lakes or the sea. The design and construction of drainage networks is

currently the main objective of many public authorities. The philosophy is to achieve a drainage system capable to avoid pipe overflow for widely accepted probabilities. The probability of system overflow, as documented in the Standard "EN 752 Drain and Sewer systems outside buildings" is presented in Table 1.

Location	Design Storm frequency[a] Return period (1 in "n" years)
Rural Areas	1 in 1
Residential Areas	1 in 2
City centres/ industrial/ commercial areas	1 in 5
Underground railway/ underpasses	1 in 10
[a] For these design storms no surcharge shall occur	

Table 1. Return periods for drainage networks, EN 752 Drain and Sewer systems outside buildings

All storm water drainage systems have a finite capacity. They are designed for specific events of certain probabilities of exceedance under specific assumptions. If the storm event exceeds the design one or the assumptions are not applicable (run-off coefficient is increased, a pipe is blocked etc) then there is surcharge or flooding.

4. Living with floods.
   Flood is a certainty. Society designs and builds the drainage networks as described above. The storm events in future are expected to be more extreme and more frequent than the ones experienced in the past (UNFCCC, 2012). Society must be prepared for living with the floods. Technology is available and provides the means for reducing the risk of loss of life or property from floods.

Another cause of flooding is coastal flooding. This occurs when the wave run-up exceeds the threshold level of the built environment (figure 2.) When the run-up is higher than the crest level of a coastal road then the coastal road is flooded.

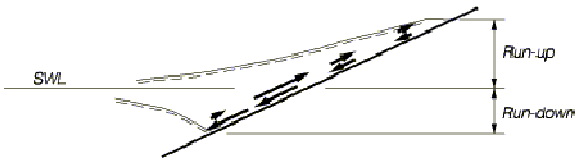


Figure 2. Wave run-up definition

In the changing environment we are living, the sea level is rising and the wave storm events are becoming more extreme and more frequent (Figure 3). As a result, flooding is becoming increasingly more extreme and more frequent.

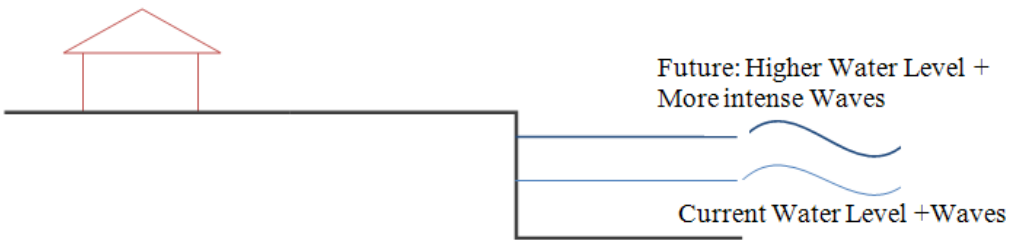


Figure 3. Coastal flooding becoming more extreme and more frequent in future.

2 FLOOD RESILIENCE TECHNOLOGY

Flood resilience technology has been available for a number of years (Gravin 2012). Within the FP7 EU funded project SMARTeST (Smart Resilience Technology, Systems and Tools) a database of available technology was compiled. There are for example products protecting the

perimeter of properties which are pre-installed and are deployed prior to the flood (figure 4), or products which are temporary ones and are transported and mounted at the flood prone areas (figure 5).

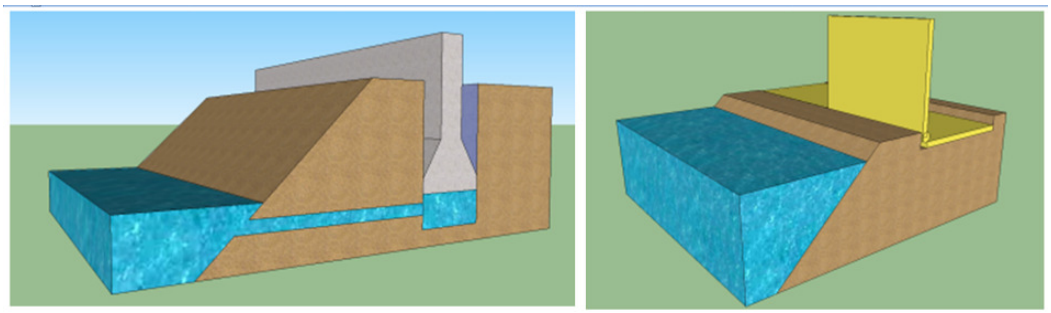


Figure 4: Pre-installed Flood barriers. Left automatically operated using buoyancy forces; right mechanically or manually erected products (sketches by Gabalda, SMARTeST)

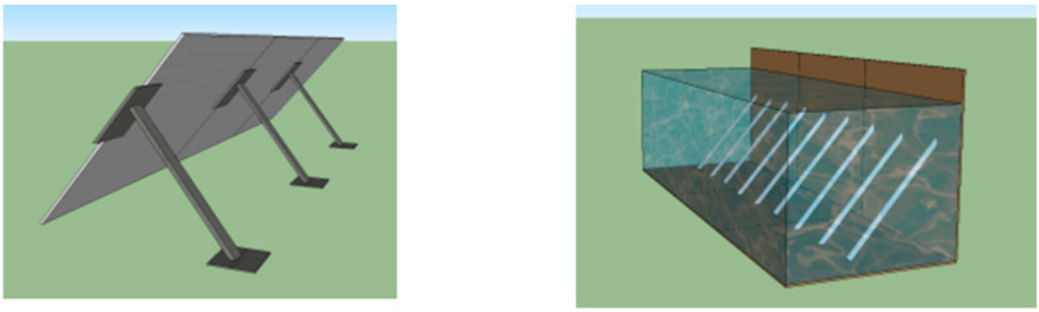


Figure 5 Temporary Perimeter Flood Barriers stablized by external forces. Left Trestle products; Right Set –square product (sketches by Gabalda, SMARTeST)

There are also products which protect the openings/ apertures of properties, like doors, services, air bricks, etc (figure 6).

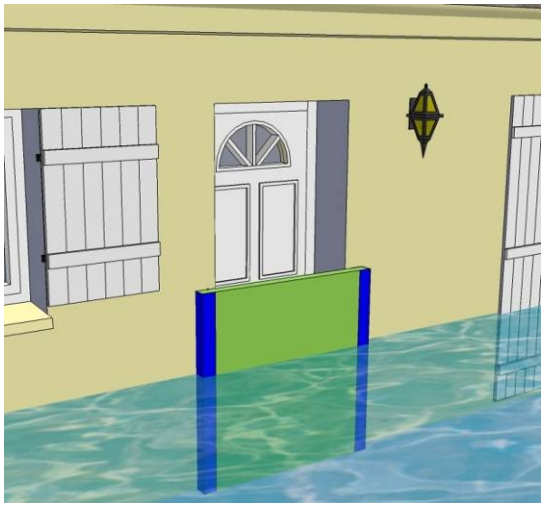


Figure 6: Demountable building aperture flood barriers. (sketch by Gabalda, SMARTeST)

All these products are supplied by specialist manufacturers. There is a continuous entry of new and improved flood barriers in the market.

3 INNOVATIVE FLOOD RESILIENCE TECHNOLOGY

A basic flood barrier (figure 7) has been developed within SMARTeST which enables the road to market for designers, manufacturers, contractors, property owners. This basic barrier has the form of a design tool which enables the sizing of the structural elements of the flood barrier and a prototype which illustrates the construction of the barrier.

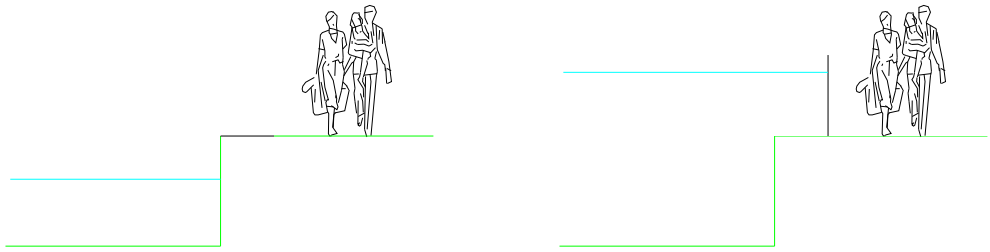


Figure 7: Basic flood barrier. This barrier may be designed by consultants and built by contractors.

The design tool, which is an open source spreadsheet, posted on the SMARTeST web page (www.floodresilience.eu) allows the user to select the design parameters. The user defines the flood level and he has the option to impose loads due to waves, current, wind and debris impact. Guidelines for the loading are given in publications by reputable organisations like FEMA and BSI. Regarding the debris, the user may select the mass of the debris, its velocity and its angle of approach, as shown in figure 8. The user may also include a spring in the barrier, an option which achieves a reduction in the force exerted on the barrier by debris impact.

The spreadsheet computes the pressure loading associated with the input data. Depending on the end support conditions, for example whether the barrier is hinged at both ends or it is a cantilever or fixed at the base and pinned at the top, the spreadsheet derives the member actions (bending moment, shear force) for each of the structural components. It then proceeds to derive the section properties required to meet the design requirements.

The various components of the basic barrier are illustrated in figure 9.

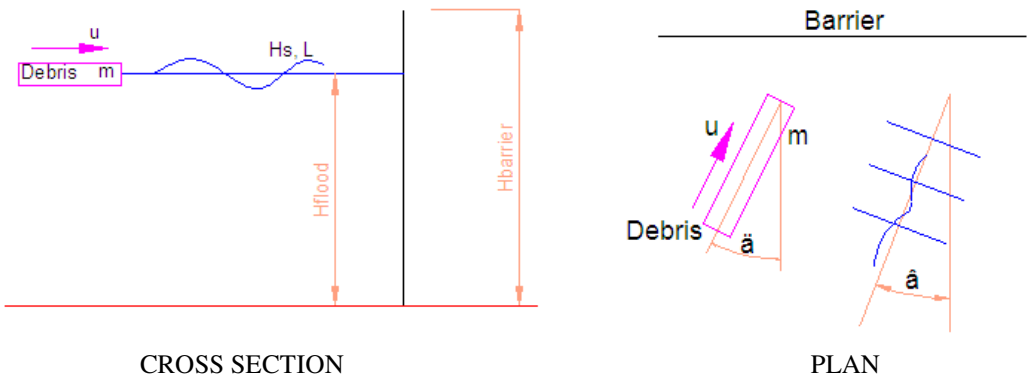


Figure 8: Input Parameters for basic barrier design

There are three basic structural elements:

- The horizontal elements, on which the pressure loading acts
- The vertical elements, which hold the horizontal elements in place
- The bracing/ end supports which transfer the loading of the vertical members to the ground/ foundations

There are two basic surfaces on the barrier:

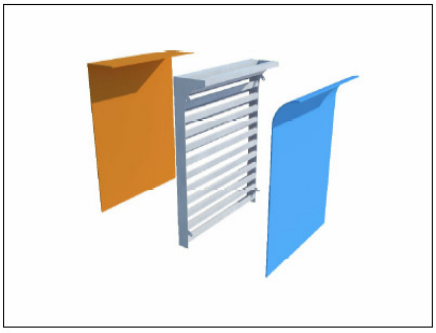
- The pavement surface which is selected by the owner in order to be in harmony with the surroundings/ environment
- The wetted surface which must provide water tightness through the barrier

In between adjacent barrier sections, there are non-structural water tightness elements which achieve the required leakage protection. These elements have a “scissor” shape so that there is overlap on both sides of the bottom support/ hinge.

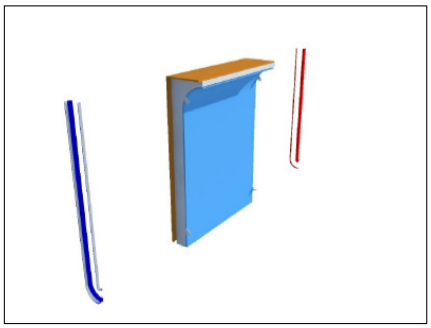
There is much scope for innovation for this basic barrier design. Innovation may be associated with:

- Impact absorption (dumpers, springs, etc)
- Mounting mechanisms (sensors for detecting flood water and activating electrical powered pistons, pneumatic struts, springs, etc)
- Locking mechanisms for barrier when closed
- Light and durable materials for harsh environments
- Vandal proof structures and materials
- Other innovative components

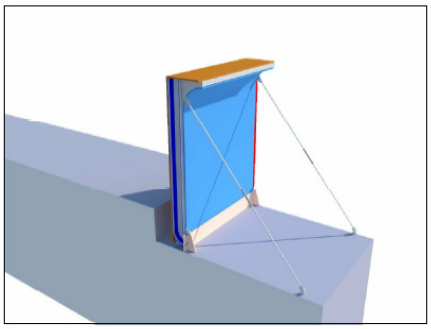
STRUCTURAL ELEMENTS
Specified by Designer Based on
Loading and Durability Requirements



PAVEMENT, WETTED SURFACES
Selected by Owner to Match
Site Environment



WATER TIGHTNESS
Various Options Depending on
Project Requirements



USER OPTIONS - INNOVATIONS:
Impact Absorption/ Dumping
Mounting / Automation Method
Barrier Locking Mechanism

Figure 9: The components of the basic barrier and the prototype as exhibited at the SMARTeST Conference, Sept. 2012, Athens

This design tool enables the road to market for:

- consulting engineers who design site specific flood barriers,
- specialist contractors who build the infrastrusture and erect the barriers
- specialist suppliers who manufacture the various components of the flood barrier
- innovatoes to come up with new materials, components for more effective and efficient technology

4 APPLICATIONS OF FRE TECHNOLOGY FOR FLOOD PROTECTION

Flood Resilience Technology may be applied in various cases, such as along the river banks (figure 10), along sea front promenades, at the entrance of underground areas (figure 11) and other similar cases.

The barrier is normally closed, pedestrian and vehicular traffic flows freely over the barrier. When there is a warning of flooding then the barrier is erected. The warning might be given from the meteorological services, or from sensors monitoring the water level in the area, or both. The barrier is erected either manually, by dedicated personnel (e.g. the fire service, the local authority, specialist contractor) or automatically (e.g. by electrically driven piston, by pneumatic strut, by buoyancy, etc).

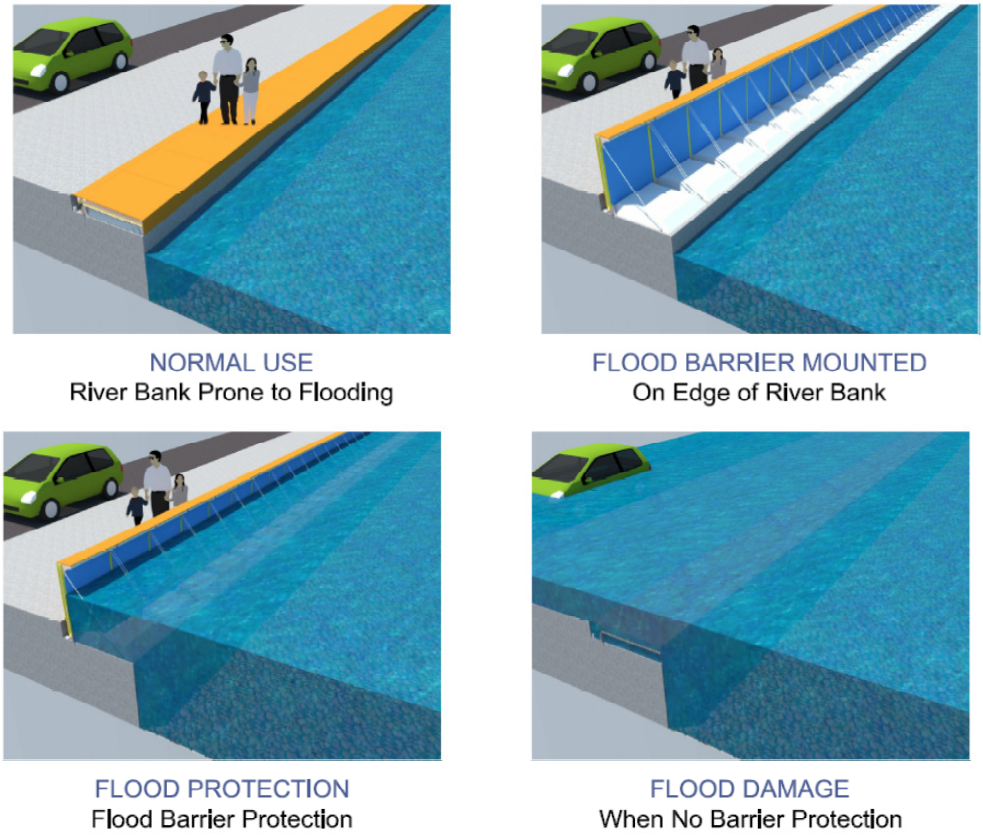


Figure 10: Illustration of basic barrier application along river bank prone to flooding

The effectiveness of the barrier depends on the flood resilience system adopted. For example there must be a system in place for the issue of the warning, the reception of the warning, the availability of the resources/ means to erect the barrier, the assurance that there are no obstacles in erecting the barrier (e.g. no cars parked on top, no debris or heavy materials stored on the barrier).

After the flood event, the flood barrier needs to be thoroughly cleaned and then closed, ready to be erected at the next flood alarm.

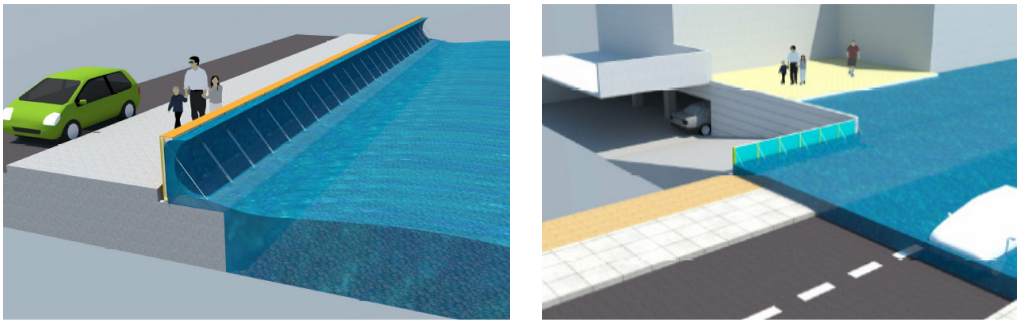


Figure 11: Illustration of basic barrier application along sea front promenade and in the entrance to underground areas

5 SCOPE FOR INNOVATION

Flood barrier technology at property level is a fairly young technology. The transposition of the Floods Directive into national law is anticipated to increase the demand for these products. New products are entering the market incorporating new materials, sensors, automations.

The introduction of the basic barrier design tool aims to enable consulting engineers to enter into this new sector and provide more designs suitable for various applications which current products cannot fulfil.

There is scope for innovation for individual barrier components like:

- Structural elements (light, durable, robust, elastic, ...)
- Paving surfaces (light, non-slip, robust, matching the surroundings, ...)
- Water-tightness elements (effective, durable, ...)
- Springs (light, durable, ...)
- Mounting mechanisms (self-opening, no-electricity requirements, ...)

There is also scope for innovation in the installation industry. Companies might be established which provide a complete service to the client, providing the design, procurement and construction of the barrier.

The user may now have three options:

1. Install a barrier which is available on the market (as in the car industry)
2. Appoint an engineering consultant to design the barrier and then select a contractor to build it (as in traditional building works)
3. Select a barrier specialist company which will design, manufacture and build the barrier (as in the elevator industry)

6 CONCLUSION

Flooding is a phenomenon society will have to live with. Many generations of engineers have been educated to design drainage systems for specific events and they know that there is always a probability that natural and man-made drainage systems will overflow and flooding will occur. Society has recognised this fact of life and the recent floods directive brings into the institutional framework the concept of “living with the floods”.

Flood resilience technology at property level, provides a promising solution to this problem, which is predicted to become more intense and more frequent in the changing environment. Flood barriers are available in the market and new products are entering the market. A new barrier design tool and a prototype barrier have been developed within SMARTeST, which enables consulting engineers to produce their own designs, fit for particular project conditions. The designed barriers may then be manufactured by various factories or workshops and built by competent contractors.

There is scope for innovation both regarding the individual components of the flood barriers and in the set-up of the new industry. Specialist companies may be set-up which design, manufacture and install the flood barriers in accordance with particular project requirements.

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