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Design to Thrive

Sustainable Retrofit for Flooding Resilience

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Abstract: In recent years, the frequency and impact of flash floods in Mediterranean coastal towns has substantially increased and will continue to rise due to a combination of Climate Change and anthropogenic factors.

In 2007, one Spanish town was tragically affected by the Girona River floods, which in few hours severely damaged and destroyed entire buildings. However, despite the severe psychological, physical and economic loss that the population suffered, there is insufficient information and awareness on the risks of recurrence of this phenomenon and the threat that it represents.

Previous research studies have proposed to free the riverbed by demolishing buildings and create more green areas. However, an architectural and environmental design approach to retrofit and adapt the damaged housing in order to improve their resilience to extreme climatic events, has never been proposed.

The aim of this project is to identify sustainable adaptation strategies for the design and construction of housing buildings affected by the floods. The following studies demonstrated that a series of mitigative and adaptive strategies can be successfully applied not only to prevent flooding and water ingress into building, but also to improve interior environmental conditions in order to maximise comfort and minimise heating and cooling energy demand.

Keywords: Flash-floods, retrofit, sustainable-adaptation, energy-demand.

Introduction

In October of 2007, a huge catastrophe hit the town of El Verger, located in the Valencian Community, Spain. Very strong and torrential rain fell into the higher altitude areas of the Girona river basin due to the *Cold Drop* phenomenon (Camarasa, 2009). The river overflowed in the floodplain area, where several towns are located.

This was not an isolated case, as the Valencian Community is historically one of the regions most affected by flash floods in Spain (Insurance Consortium of Geologic and Mining Spanish Institute, 2006). One of the most important and famous cases is the 1957 flood in Valencia, which completely destroyed the city and killed hundreds of people (J.J.S.I., 2011). It was a catastrophe without precedents, and due to the unexpected consequences of the floods, the Government at that time made a radical decision to dry the Turia river basin on its way through the city (Angus Baker, 2013). Nowadays, this feature makes Valencia the only city in the world to have its green core, activity, and cultural hub located inside an old river basin.

Thus, this project is based around the common and important issue of flash flooding, which due to climate change and human action, will become more and more frequent in the

future. Can architects improve the situation and reduce the negative impacts of extreme weather events and increased building construction and urban densification through a climatic and environmentally responsive perspective?

Following a literature review and background research on the responses by local hydrology experts, one of the proposed solutions (Palencia, 2015) was to remove all buildings inside the danger zone, and create green areas around the river, which would absorb rain water and reduce runoff considerably. However, this solution is quite unrealistic and difficult to implement. Apart from the obvious economic impediments, it would have a high-impact on the population. Residents would be required to leave their family houses, and would lose not only their homes but a huge part of their memories and life moments. Nevertheless, another solution, more sensitive to the social context and feasible was proposed and analysed: to **retrofit of the existing housing stock to improve their resilience and comfort conditions**. A good explanation of all problems and consequences of this research can be found in Fig. 1.

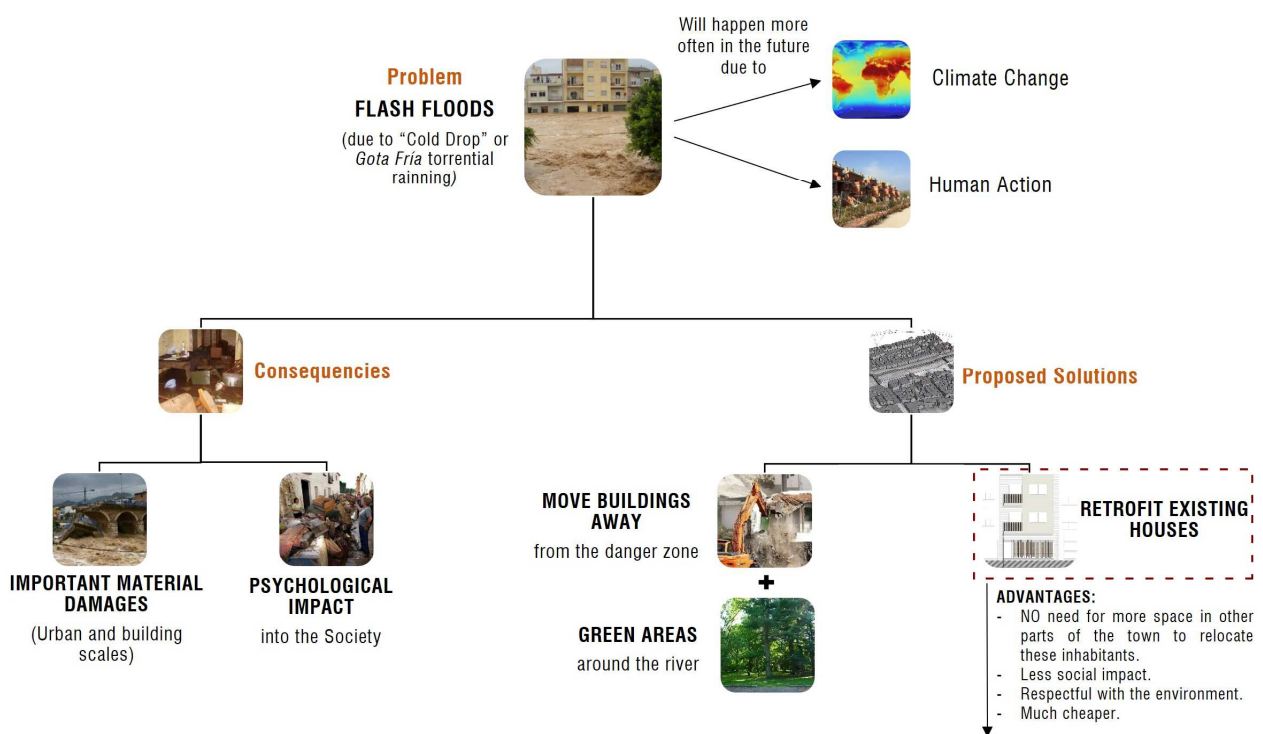


Figure 1. Concept diagram of the main problem, consequences and proposed solutions of El Verger 2007 floods.

Urban Context. El Verger Historic Urban Growth

The Girona River has always been the articulatory axis of El Verger, and the first settlements were located in the area where the church is currently placed. This is precisely located on the highest point of the town, which means that our ancestors were aware that this would be the safest place.

The two maps on Fig. 2, demonstrate that urban density in 1955 was highest on the West part of the river, and the urban tendency during the last 50-60 years has been in the same direction. However, building development started to grow on the other side of the river at that time too, and now these structures shape an important part of the total urban area of the town. In Fig. 2, the urban sections of 1955 and 2016 show this urban density change, especially on the East side of the river. Further, it is important to see how human actions have transformed

the riverbed basin. Before it had natural slopes on both sides, and now reinforced concrete walls have been placed, and the width has narrowed.

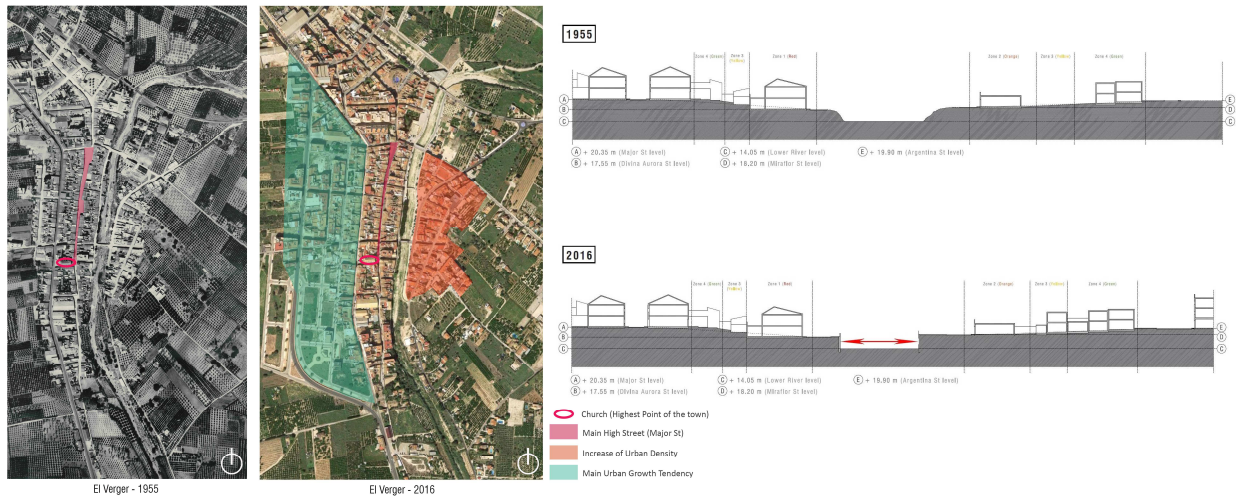


Figure 2. Historic (1955) and present maps of El Verger and urban sections of these periods.

Urban Context. Present

The Planning Authority of El Verger established after the 2007 floods, 4 flooding zones depending on the flood water level arrived to every building (El Verger Urban Council, 2015). The first zone is red and it represents the most affected buildings. The level of the water reached the first floors (around 3 m high). The orange zone includes the second most affected buildings and the water reached between 2 and 2.5 m high. The yellow zone is the most reduced zone and the buildings experienced a medium level of flood water, between 1 and 2 m high. Finally, the green zone, includes a large number of houses, which were less affected, but still suffered lots of physical damages. The level in this zone reached 1 m high or less. Based on this zoning, two case studies were chosen as part of this study to investigate more deeply their issues. One case is located in the red high flood risk zone (Case Study 1, a terraced single-family house) and one in the orange zone (Case Study 2, a terraced apartment building), both marked on Fig. 3 (urban cross sections with and without flood water) and Fig. 4 (urban plan of the studied area with floods zones shaded).

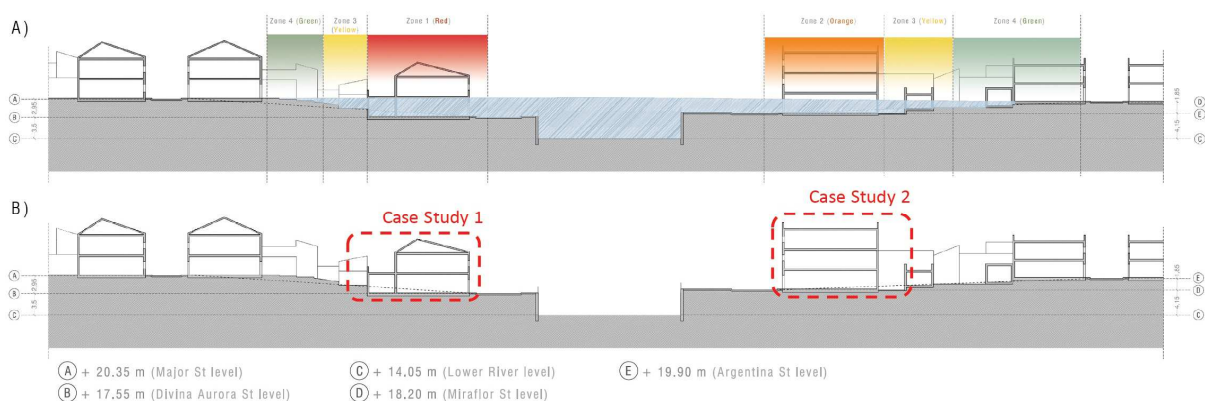


Figure 3. Urban cross section of El Verger indicating (A) flood zones and colour classification; and (B) the two case study buildings.



Figure 4. Urban plan of El Verger indicating flood zones and colour classification.

Climate Analysis

El Verger is included into the mild Mediterranean climate area and as such it presents these general features: a) very mild winters, softened by the sea action; b) long, dry and very warm/hot summers; c) almost 3.000 hours of sunshine per year; d) precipitations in spring and autumn; e) very strong precipitations risk (*Cold Drop*) in September and October; f) No precipitations in the rest of the year; g) High relative humidity (average 65 %); h) Optimal number of hours of daylight (ref). As shown in Fig. 5, where the Valencia Cumulative rainfall is explained comparing present and A1B Future Scenario in 2050, due to climate change, a general reduction in precipitation will be experienced throughout the year. Moreover, the main precipitation data will be concentrated in October creating a “dangerous peak”.

Figure 5. Valencia Cumulative Rainfall: Present (left) and A1B Scenario in 2050 (right). (Meteonorm 7).

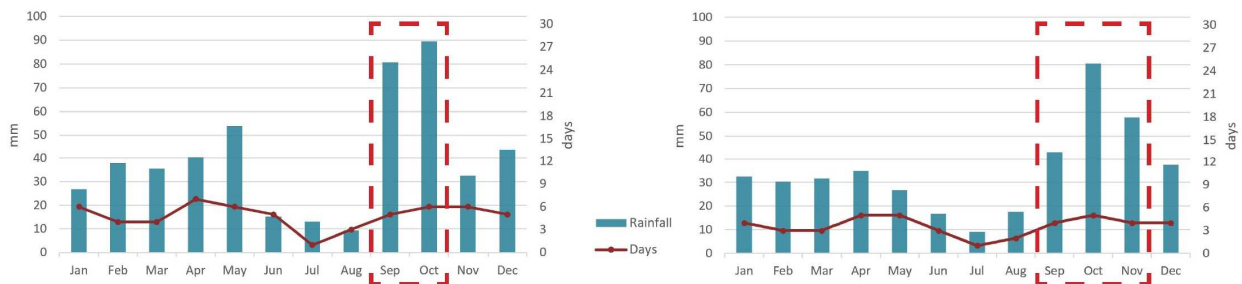







Figure 6. Valencia Relative Humidity: Present (left) and A1B Scenario in 2050 (right). (Meteonorm 7).

Building Scale Analysis

Considering the most typical building typologies affected by 2007 floods and El Verger population pattern, the following cases were selected: 1) one terraced single-family home with one traditional family and 2) one apartment building with one widow grandmother and a single mother with two daughters. Considering all the problems and risks these buildings are exposed to, and after having a broad idea of which are their environmental and climate conditions, one of the most important things to be outlined will be the strategies to be applied. Based on literature review, precedents, fieldwork and urban analytic work findings, the following case scenarios collected on Table 1 have been chosen as best ideas.

Table 1. Cases table which the main design proposals and where are going to be tested, together with the best zones to be applied to.

Case n.	Leaves the water coming inside the building?	Tested on	Best Zones to be applied to
CASE 1. Leave the GF as a semi-open space & move residential spaces to the upper floors + Raise one step the GF and make a drainage floor system	Yes 	Case Study 2 Terraced Apartment Building	Zone 1 (Red) Zone 2 (Orange)
CASE 2. Shell around the GF walls + Composite Flood Doors & Windows	No 	Case Study 1 Terraced Single-Family House	All zones
CASE 3. Raise two steps the GF level on a Suspended Floor + Optional Case 2	No 	Case Study 2 Terraced Apartment Building	Zone 3 (Yellow) Zone 4 (Green)

Design Applicability

Two different techniques were proposed to allow the water being drained easily through the ground and to avoid the damp water rise through the walls or other building elements.



Figure 7. Two steps and a high suspended floor (right) and one step and gravel drainage floor (left) sections.

The first one would be a) to build two steps and a high suspended floor (Case 3, Table 1); and, b) to rise one step into the GF level and create a gravel drainage floor (Case 1, Table 1). Also, compare both strategies on Fig. 7 building sections. Both options are feasible because the current ceiling height is 3.2 m and one of these techniques will only take 0.36 m. Apart from this, the GF doors would be composed by open wooden slats to allow the water coming in (in both façades) (see Fig. 8).



Figure 8. Virtual images of the of the proposed flood resilience design for Case Study 2: Terraced Apartment Building, with and without flood water, as it would be most of the time.

Daylighting Studies

Apart from solving the flooding problems, one of the main goals of this research was to carry out at the same time a sustainable retrofit of the houses affected. One of the important things to reduce the energy demand of the buildings are the daylighting studies. A considerable improvement will be achieved by modifying the interior layout of the apartments. As an example, Case Study 2 apartments have their dining-rooms with no openings to the exterior and they are completely dark and poorly ventilated (Daylight Factor = 0%). Additional strategies will be also applied such as: 1) increase the window to floor area in both elevations (from 7.81% (East) and 9.21% (West) on the main bedrooms to 15%;

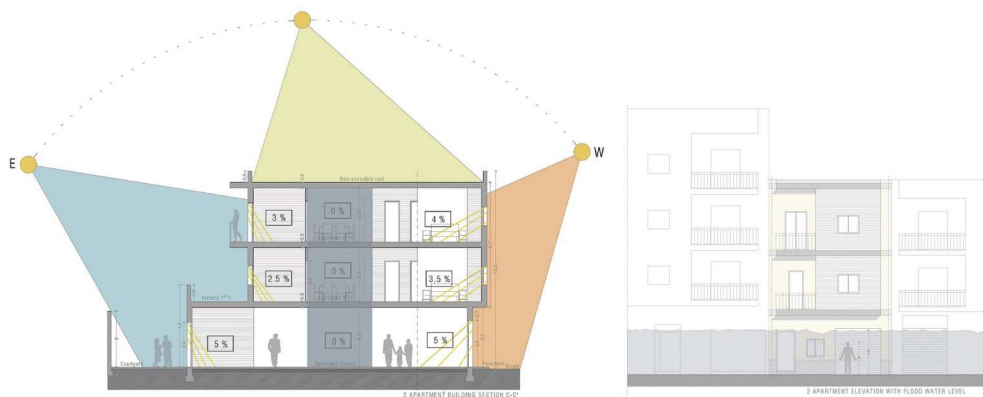


Figure 9. Current section with daylight factor percentages and solar radiation plotted, together with the current elevations with the flood water level arrived to this building in 2007 floods.

2) add two skylights above the staircase; and, 3) build a glass partition into the corridor of the apartments entrances (which before was also completely dark, DF = 0%). Fig. 9 and Fig. 10 illustrate the current and proposed strategies in section and elevation, respectively.

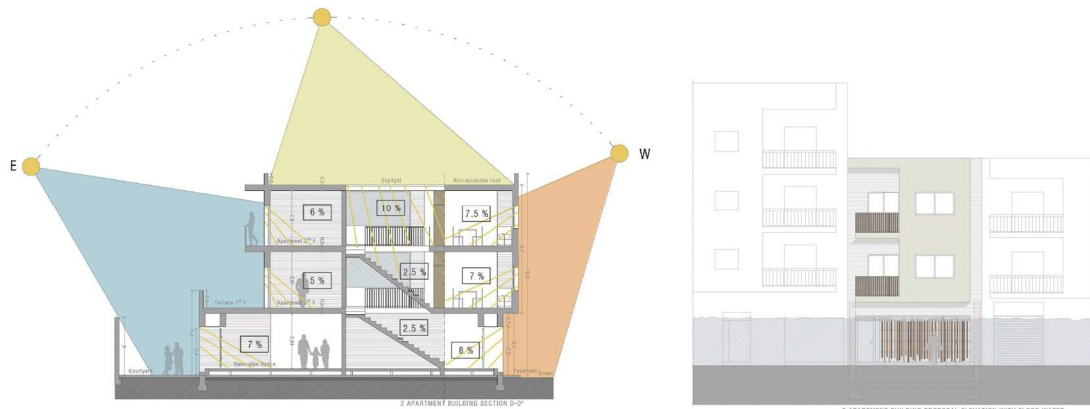


Figure 10. Proposed section with daylighting percentages and solar radiation plotted, together with the proposed elevation with the flood water level arrived to this building in 2007 floods.

Ventilation Strategies and Thermal Performance

Another important aspect to have into consideration to improve the comfort conditions of the interior of the houses and also to reduce some levels of uncomfortable relative humidity, will be to apply several ventilation strategies. Same as before, this will be important to carry out a sustainable design refurbishments. These ventilation strategies are based on cross ventilation (CV) plus stack ventilation (SV) through the stairs skylight, recording before less than 10 ACH (Buoyancy + Wind Driven) and more than 45 ACH after the strategies applied (almost achieving the necessary for cooling on hot seasons). See Fig. 11 to understand this ventilation strategies in Case Study 2 (Apartment Building). This will also be related to thermal performance, because good ventilation levels can reduce significantly the overheating inside of a space and consequently the need for air conditioning (and therefore the energy demand). Thus, the temperatures will drop from more than 30-32°C (in summer) or rise from 12-14°C (in winter) on current situation to be between 19°C to 21°C in all seasons of the year (considered to be inside the comfort band) (see Fig. 12).

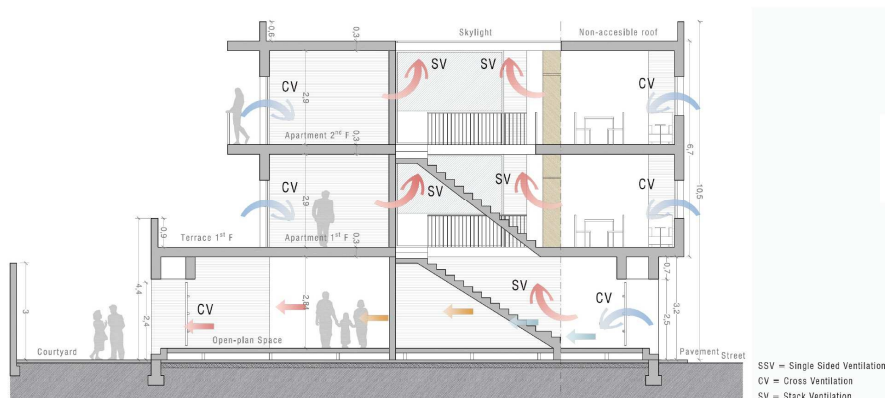


Figure 11. Section of the proposed ventilation system in Case Study 2 (Apartment building) and the different air movements plotted.

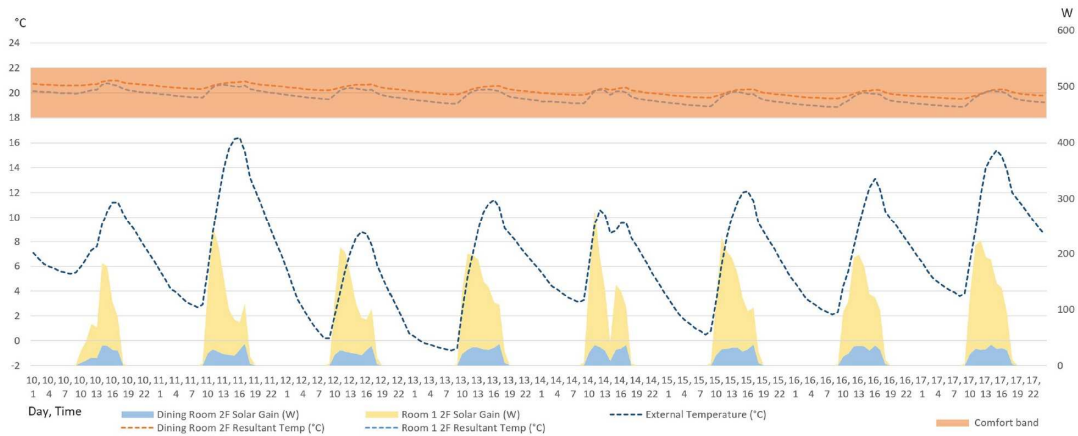


Figure 12. Thermal performance of this case scenario in some of the interior rooms (10-17th January).

Conclusion

Cold Drop affects to all eastern Mediterranean areas and landscape features are almost identical in all cases (relative short river basins with pronounced height difference between its source and mouth). Design interventions studied on this research show that by applying simple strategies to buildings, reducing paved surfaces, creating more interior courtyards, etc. we can significantly reduce the flood damage; and, most importantly, without moving any house or inhabitant. Then, at the same time, if these strategies are made from a sustainable point of view, we can bring all the occupants into a comfort situation almost all year round inside the interior spaces, just changing the W to F ratio, materials or ventilation habits (as we have seen on last sections).

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