STIFFENING THE STRUCTURE

HAZARD

RAINFALL AND FLOODS

COASTAL DYNAMICS

GEOTECHNICAL DROUGHTS

STORMS AND STRONG WINDS

IMPLEMENTATION STEP

CONSTRUCTION

AREA OF ACTION

FOUNDATIONS

ENVELOPE

COST

€ € €

low medium high

LEVEL OF SKILL

medium

As extreme weather events intensify and multiply, the integrity of buildings is more threatened than ever. Stiffening the structure of buildings is essential to make them stronger and more stable. A perfectly rigid building structure is able to withstand the distortions generated by soil and air movements and water pressure.

IMPACTS

Stiffening a building's structure **limits the risk of cracks** due to soil movement (shrink-swell) and **reduces the damage caused by the mechanical action of water in** the event of floods or coastal flooding. However, its effectiveness cannot be guaranteed if the expected level of flooding is greater than 1m (as the pressure exerted by the water could undermine the integrity of the structure of the building). In this case, it is advisable to allow the water to enter the building, after first protecting the building by using water-resistant materials and securing the occupants and the building's essential equipment.

Improving the stiffness of the building structure also helps to **limit the risk of collapse due to air pressure in the event of storms and high winds**. These risks are particularly high in the French overseas territories.

INSTALLATION GUIDE

Where there is a risk of a distortion of the structure, the best option is **chaining**. This involves incorporating steel reinforcement into suitable concrete, a process that is already widely used in large-scale construction projects.

In France, the unified technical reference documents (*DTU*) 20.1 and 23.1 recommend installing **horizontal chaining** at the level of each floor or slab in the building, and vertical chaining for all load-bearing walls, with the exception of natural stone masonry. Ideally, **chains** should also be installed **on the gable slopes** (at roof level). Particular attention should be paid to the **connections between horizontal and vertical chaining**, especially in the corners of the building.

Other techniques for stiffening the structure of a building include installing lintels above openings and creating a "monoblock" base. The latter is a reinforcement technique that involves creating a solid base for the building. This involves covering the basement with a raft foundation (a continuous concrete slab extending over the entire surface of the building) or crawl space floors, rather than a slab-on-grade (on the ground) or partial basement. This approach offers a number of advantages in terms of stability and load resistance, as it allows loads to be better distributed over a larger surface area.

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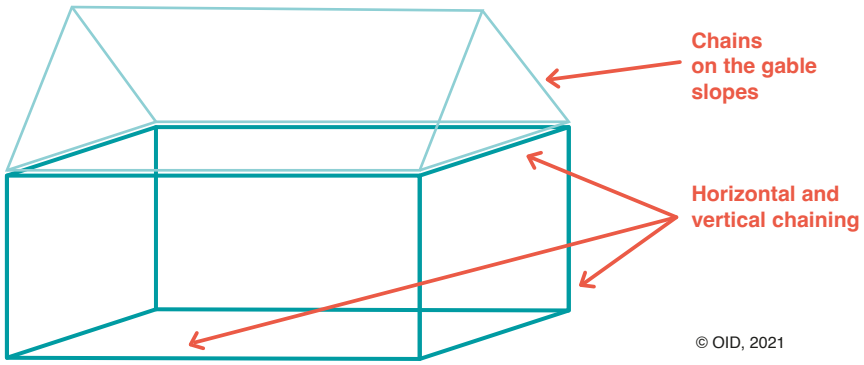
EXAMPLES OF BUILDING CHAINS



WEAK POINTS AND STRONG POINTS

⊕ Ideally, chaining installations should follow the **recommendations of the French unified technical reference documents (**DTU**) 20.1 and 23.1**. Although these documents are not compulsory, they are strongly recommended. Particular attention should be paid when building detached houses, as builders of this type of property sometimes ignore the provisions of the DTUs.

⊖ Installing chaining in concrete **requires structural work**. It is therefore reserved for new buildings and existing buildings undergoing complete renovation.

⊕ For existing buildings, the **installation of a wall tie** to stop the expansion of a crack or limit the weakening of the building can be considered. This type of device is often used in old dwellings, particularly when built of stone.

MALADAPTATION

Maladaptation can result from the following:

Increased seismic vulnerability

Stiffening the structure of a building could increase its vulnerability to earthquakes. Excessive rigidity can make the structure less able to absorb seismic vibrations, jeopardising the safety of occupants.

Transfer of stress to other structural elements

When a specific part of a building is reinforced to resist external forces applied to the structure, stress can transfer to the unreinforced parts. For example, by stiffening load-bearing walls, stress could shift to unprepared foundations, thus transferring the spatial vulnerability. It is essential to consider the structure as a whole in order to anticipate these consequences and take appropriate measures.

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MONITORING INDICATORS

ESSENTIAL RECOMMENDATIONS WORTH THINKING ABOUT

- INSTALL A WALL TIE ON EXISTING BUILDINGS IN THE EVENT OF CRACKS OR WEAKENING
- INSTALL CHAINS WHERE THERE IS A RISK OF DISTORTION OF THE STRUCTURE
- PLACE LINTELS OVER OPENINGS
- STIFFEN FROM THE SUBSOIL (RAFT FOUNDATION, FLOOR OVER CRAWL SPACE, ETC.)

MONITOR MY ACTIONS FOR CLIMATE CHANGE ADAPTATION

+/– : Quantitative indicator ★ : Qualitative indicator

INDICATORS OF MEANS	INTERPRETATION
+/– Slope of structure compared with control situation* (mm/minute)	To be minimised
+/– Comparison between the relative micro-deformations of the structure and those of the control situation* (mm)	Relative micro-deformations of the structure with improved stiffness < control situation*
+/– Percentage of cracks wider than 1 mm in and/or longer than 10 cm that are monitored (%)	To be maximised
+/– Percentage of essential recommendations followed (%)	The maximum number of recommendations must be implemented

INDICATORS OF RESULTS	INTERPRETATION
+/– Number of cracks wider than 1 mm and/or longer than 10 cm	No increase in the number of cracks
+/– Number of cracks that have widened and/or lengthened, including those wider than 1 mm and/or longer than 10 cm	No widening of cracks
+/– Financial, material and/or human damage caused by mechanical action in the event of flood or coastal flooding	To be minimised
+/– Financial, material and/or human damage from collapses due to air pressure in the event of storms or high winds	To be minimised

**The control situation is defined by the parameters set to isolate the influence of the adaptive action (similar conditions: weather, time of measurement, space, etc.).*

CONCEPT / DEFINITION

- A **wind** is generally considered to be **violent**, and therefore dangerous, when its mean inland wind speed reaches 80 km/h with gusts of 100 km/h. However, this threshold varies from region to region, and is for example higher for coastal areas and the south-east of France. On land, a storm is defined as a low-pressure system generating gusts in excess of 90 km/h (Météo-France, 2023).

TOOL

- Inclinometers are instruments used to precisely measure the angles of slopes/tilts and detect movements and abnormal slopes in a structure.
- Strain gauges include **electrical strain gauges/vibrating string gauges/fibre optic gauges** and measure relative micro-strains (mm). These cost-effective gauges are easy to weld, glue or embed in concrete, and can also be used for dynamic measurements.
- A **crack-width gauge** is primarily designed to measure the linear opening of a specific crack, whereas an extensometer is a more comprehensive instrument that measures various crack parameters (deformation, width, length, shape, etc.), monitors the crack in several directions and records variations over time.

REGULATION / CRITERIA

- **Cracks wider than 1 mm** should be monitored more closely. The length depends on the component concerned, but it is advisable to monitor cracks of 10 cm or more (Baticopro, 2020).

FIND OUT MORE

BRGM (2009), *Rapport final du projet ARGIC (Analyse du Retrait-Gonflement des Argiles et de ses Incidences sur les Constructions)*

Ifsttar and Ineris (2017), *Retrait et gonflement des argiles – Analyse et traitement des désordres créés par la sécheresse*

French Ministry for Ecological Transition (2008), *Le retrait-gonflement des argiles - Comment prévenir les désordres dans l'habitat individuel ?*

French Ministry for Ecological Transition (2021), *Construire en terrain argileux – Réglementation et bonnes pratiques*

French Ministry for Ecological Transition (2022), *Construction et risques sismiques*

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