ADAPTING THE FOUNDATIONS

HAZARD

RAINFALL AND FLOODS

COASTAL DYNAMICS

GEOTECHNICAL DROUGHTS

IMPLEMENTATION STEP

CONSTRUCTION

RENOVATION

AREA OF ACTION

FOUNDATIONS

COST

€ € €

low medium **high**

LEVEL OF SKILL

high

Foundations are essential to a building's stability: they transfer the weight of the building structure to the ground and help prevent settling and water infiltration. There are two main types of foundation: shallow foundations (which can be laid when the ground is stable) and deep foundations (laid when the surface layers of the ground are too fragile).

IMPACTS

Many weather-related losses are caused by poorly adapted and/or designed foundations. **Problems with foundations** can result in **cracks** in walls, **deformed** door and window frames, or a difference in floor levels.

Adapting foundations limits the damage caused by soil movement in the event of shrink-swell and scouring (partial or complete loosening of the foundations) in the event of floods or coastal flooding.

INSTALLATION GUIDE

The installation of foundations adapted to climate risks requires:

1. **Knowing the nature of the soil and the building**: it is important to carry out a soil survey beforehand to detect any risks of ground movement due to shrink-swell. A cross-analysis of the characteristics of the ground and the building should determine the type of foundation to be used and the depth at which the foundations should be anchored: in cases of unstable ground, risk of subsidence, or heavy loads, deep foundations will have to be laid.

2. **Anchor the foundations evenly**: on sloping ground, downstream foundations should be anchored deeper than those upstream, so that they lie on the same layer of soil.

3. **Minimum footing depth**: as a general rule, for surface foundations, a minimum footing depth of 0.80 m is considered necessary in low- to medium-risk areas and 1.20 m in high-risk areas for detached houses (Agence Qualité Construction, 2004).

If any damage appears, particularly cracks, it's advisable to carry out an examination of the structure and a soil survey to identify the issue. Underpinning (reinforcing the foundations by redistributing the loads) may be an option. In this case, two main techniques can be used: increasing the width of the existing foundations or adding new foundation elements deeper down.

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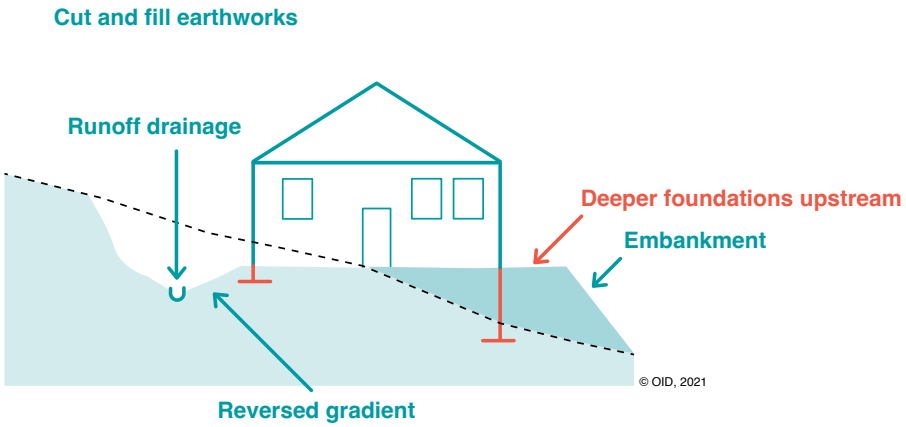
ADAPTING FOUNDATIONS ON SLOPING TERRAIN



Source: French Ministry for Ecological Transition (2008)

WEAK POINTS AND STRONG POINTS

⊖ Underpinning foundations is a **very costly and difficult** operation, as it brings a risk of the building collapsing or settling. For renovations and extensions, it may be preferable to uncouple the structural elements to improve the stability of the building.

⊕ In order to preserve the integrity of foundations and thus avoid the need for this process, **preventive solutions** to control soil moisture levels can be implemented at building level. Adaptive measures to prevent flooding and coastal flooding can be implemented at local level (retention basins, soil desealing, etc.).

⊕ Ideally, foundations should be laid **in compliance with the recommendations of the French Unified Technical Documents** (*DTU*) 13.11 and 13.12 for shallow foundations and 13.2 for deep foundations.

⊕ The intensification of droughts and shrink-swell has seen the **French government take up the issue,** with the aim of reducing the number of related claims: as part of the *ELAN* law of 2018, since May 2019 it has been compulsory to carry out two soil surveys when selling a building plot intended for individual housing or building a house, and a map of areas exposed to clay swelling and shrinkage was published in July 2020.

! MALADAPTATION

Maladaptation can result from the following:

Disturbance of the soil and surrounding structures

Some foundation adjustment techniques, such as the addition of reinforced concrete counterwalls or struts, aim to reinforce structural stability by distributing loads and resisting lateral forces like wind and ground pressure. However, these adjustments can exert undesirable lateral forces on the surrounding soil, altering its ability to support loads and potentially disturbing neighbouring structures.

Disturbance of the soil's natural hydraulic balance

Injecting resin or mortar into the ground or introducing deep foundations can also disrupt the soil's natural hydraulic balances, affecting underground flows and groundwater recharge. These hydraulic alterations can lead to local flooding or drought, and impact the long-term stability of surrounding structures.

Inadequacy of climate change adaptation measures

Note that if climate forecasts are not sufficiently anticipated, foundations adapted for current conditions may not be able to withstand future extreme weather events such as storms, floods and prolonged drought. This could make buildings and infrastructures more vulnerable to these events, compromising their resilience and sustainability.

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MONITORING INDICATORS

ESSENTIAL RECOMMENDATIONS WORTH THINKING ABOUT

- INCREASE THE WIDTH OF EXISTING FOUNDATIONS
- ADD DEEPER FOUNDATION ELEMENTS
- CARRY OUT INJECTIONS (EXPANDING RESIN, MORTAR, ETC.)
- ADD PILES AND/OR MICROPILES
- ADD ABUTMENTS, TIE RODS, REINFORCED CONCRETE COUNTER-SAILS, ETC.
- ADD SOIL INJECTION ANCHORS
- CARRY OUT A SOIL SURVEY

MONITOR MY ACTIONS FOR CLIMATE CHANGE ADAPTATION

+/− : Quantitative indicator ★ : Qualitative indicator

INDICATORS OF MEANS	INTERPRETATION
+/− Percentage of cracks wider than 1 mm and/or longer than 10 cm (%) that are monitored	To be maximised
★ Water status of the foundation soil defined by a hydrometric soil survey defining the control situation*	-
+/− Comparison between water tension and the control situation* (centibars)	Stabilisation over time
+/− Percentage of essential recommendations followed (%)	The maximum number of recommendations should 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
+/− Difference in level between several reference points distributed over the foundations of a building at the same depth, compared with a control situation* (m)	The difference in level between the reference points should vary as little as possible (to avoid differential settlement of the foundations).

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

TOOL

- 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.
- **Differential levelling** is carried out using levelling tools such as spirit levels, lasers or precise levelling instruments.
- **Soil tensiometers** are used for annual monitoring of tensiometric data (continuous measurement in real time). Cerema is currently experimenting a process called MACH (*MAison Confortée par Humidification*): when the tension in the soil reaches a critical level indicating that the soil is too dry (defined in relation to the hydrometric study), the foundation soil is moistened by injecting rainwater that has been collected and stored. This water is diffused into the ground by gravity through several injection points distributed around the cracked facades. This stabilises buildings damaged by shrink-swell.

REGULATION / CRITERIA

- **Cracks wider than 1 mm** should be monitored more closely. The length depends on the component concerned, but it's 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 CSTB (2017), *Retrait et gonflement des argiles - Protéger sa maison de la sécheresse : conseils aux constructeurs de maisons neuves*

LAVARDE, C. (2023), *Rapport d'information fait au nom de la commission des finances sur le financement du risque de retrait gonflement des argiles et de ses conséquences sur le bâti* (Information report on behalf of the Finance Committee on the financing of the risk of clay shrinkage and swelling and its consequences on buildings).

OID (2024), *Fiche aléa – Sécheresses et RGA* (Droughts and shrink-well of clays)

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