

Lightweight Recoverable Foundations on Suitable Ground

Abstract: *One of the greatest challenges to be faced in the fight against climate change in the construction sector is the fact that (non-traditional) conventional solutions are routinely accepted despite their high environmental impact. In particular, reinforced or mass concrete foundations are used at almost all sites, but they require a large amount of material, involve high emissions (some toxic), are extremely heavy and cannot be recovered. It is surprising to observe that most recent constructions in which the environment is taken into account use such foundations.*

*This paper presents the results of the research carried out on **lightweight recoverable foundation solutions**. The aim is to dramatically reduce the amount of material and allow the foundations to be deconstructed and recycled along with the rest of the building, leaving the land clear for reuse.*

Lightweight foundations, recoverable foundations, prefabricated foundations, site investigation.

Lightweight recoverable foundations

Lightweight recoverable foundations can be divided into two major groups: prefabricated and completed-in-situ foundations (cast-in-situ foundations are not considered because they pollute the subsoil and require large amounts of concrete).

LIGHTWEIGHT RECOVERABLE FOUNDATIONS ON SUITABLE GROUND	
Prefabricated foundations	Cylindrical and under reamed piles of wood, steel or concrete - Sheet piling – Strips and hollow or solid blocks - Supports, tripod, bases, piers, plates - Floating boxes or drums - Helical and screw piles - Grids
Completed-in-situ foundations	Semi-precast foundations and formworks - Micro piles - Composite piles

Timber piling (fig.1 to 3) is the lowest cost deep foundation material and lasts for over 100 years, with a natural taper that increases friction capacity. It can be easily delivered, handled and installed using existing driving equipment at close spacing, minimizing expensive floor slab thickness and resisting attack from acidic soils. It is also unaffected by stray electrical currents and no corrosion protection is required, taking advantage of a plentiful, natural renewable resource.

Steel piles (fig.4 to 6) are either pipe piles or beam sections like an H-pile. driven into the soil by repeated impulsive loads. They may be cylindrical or expandable. Expandable mechanisms significantly improve the efficiency by rising the ratio bearing capacity / self weight. Opening extensions is accomplished during the final phase of the driving.



Fig.1,2,3: Timber piling is the oldest foundation system, extensively used in many applications. It has recently emerged as a low-energy, cost-effective sustainable solution (fig.1,2,3 and: <http://www.geoforum.com/info/pileinfo/view.asp?ID=56>)

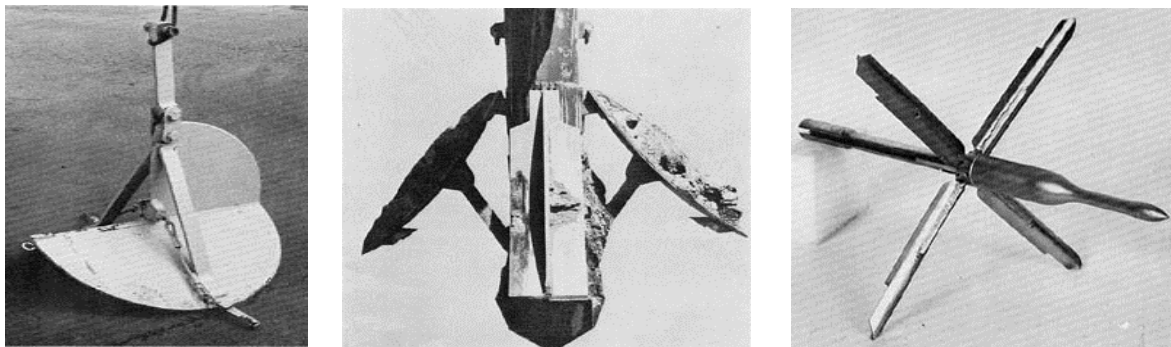


Fig.4,5,6: Expandable steel piles: Y-shape, umbrella pile and Magnavox Company pile.

Precast concrete piles (fig.7 to 9) are suitable for all applications and ground conditions and provide a very cost-effective solution. They are quick to install without producing spoil or arising material in the process, providing a further saving on waste disposal costs.

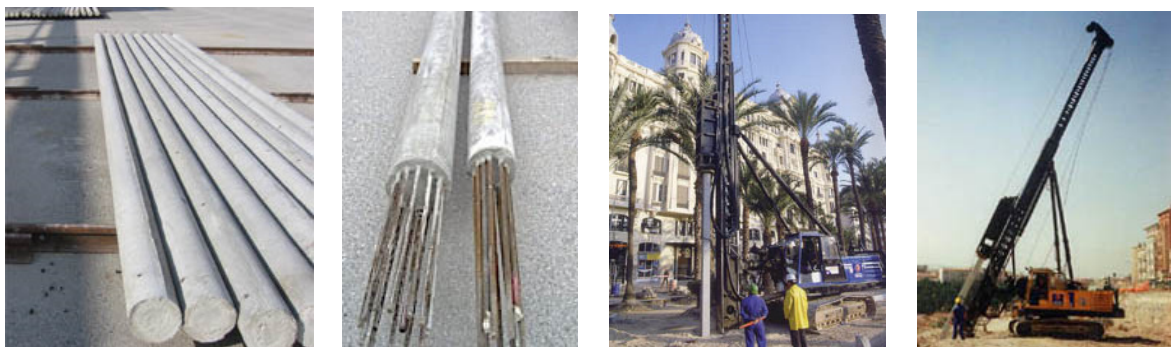


Fig.7,8,9: Precast reinforced concrete piles may be driven vertical or inclined. Inclining the piles increase the horizontal bearing capacity.

Sheet piling (fig.10 to 12) is a form of driven piling using thin interlocking sheets of steel to obtain a continuous barrier in the ground. The main application of sheet piles is in retaining walls and cofferdams but single or combined units may be employed as recoverable lightweight foundation. Vibrating hammers and cranes are used to install them.

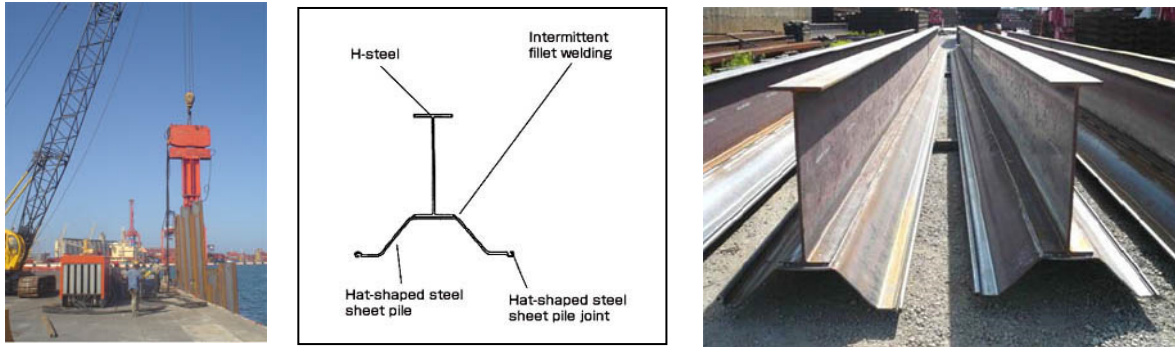


Fig.10,11,12: Installation of sheet-piles by vibro-hammering (left) and combined steel sheet pile.



Fig.13,14,15: Prefabricated strip footings, including tie beams, can be placed on the surface or buried.

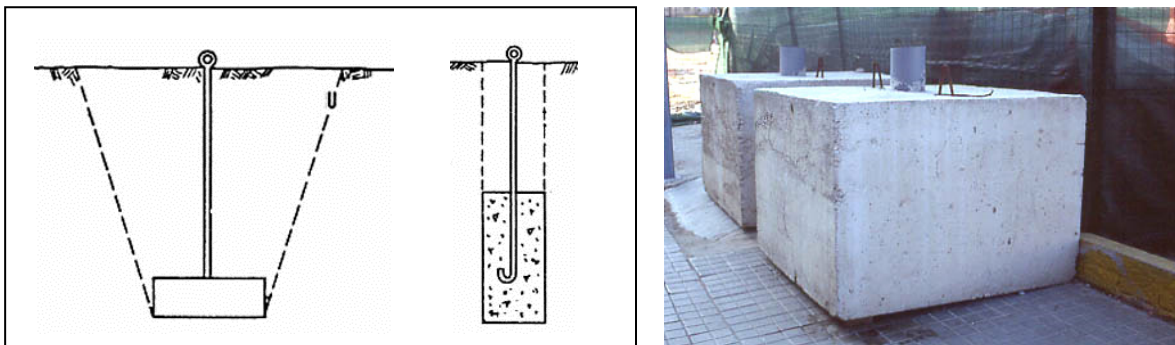


Fig.16,17,18: Precast hollow or solid blocks and footings are usually buried. They may be placed on the surface in case of hard soils and bed rock to prevent or reduce excavation.

Supports, tripods, bases and plates (fig.19 to 23) are ideal for light buildings supported by almost all kind of soils, provided they have some resistance. Single- family, semi-detached and row houses, mobile and manufactured homes, prefabricated 3D modules, emergency shelters, temporary dwellings and the like do not usually need large amounts of poured concrete, keeping in mind however that hazardous conditions such as strong winds and earthquakes may require complementary anchors to prevent overturning and uplift. Even if this was the case, note that anchoring to the soil is much more efficient than relying on weight.

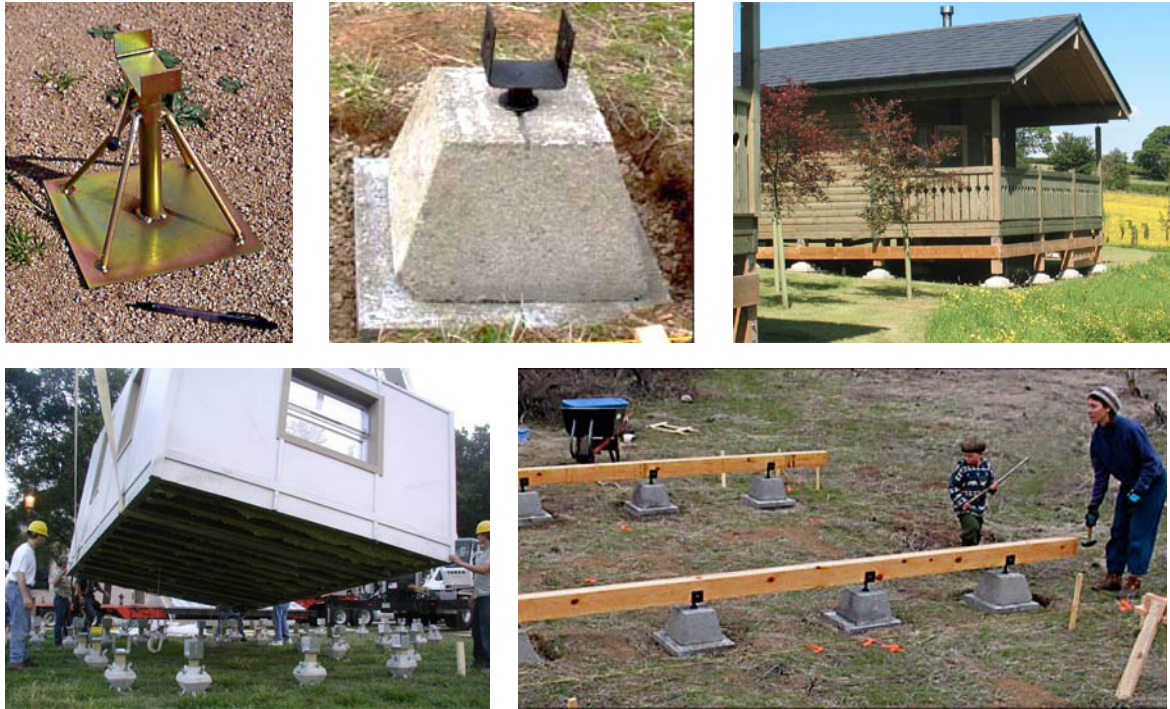


Fig.19,20,21,22,23: Light supports for light houses. Soft soils require compaction.

On soft and very soft soils it is also possible to avoid piling concrete by means of **floating boxes or drums**. It is the case of Holvast & Van Woerden: “De Fantasie” freestanding house in Almere (fig.24 to 25), a small residential core surrounded by scaffolding creating a spacious “outer house” which enwraps the living section like a well-fitting jacket.

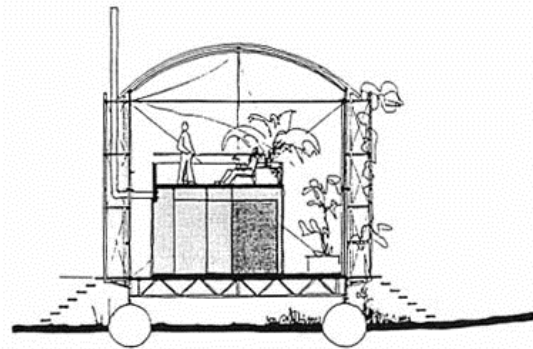


Fig.24,25: The foundations consist of hollow floats that could be used both on dry land and on water

Screw piles (fig.26 to 28) are slender shafts, having one or more single-turn helical surfaces, screwed into the soil. The diameter of the helixes, the number of the helixes, the magnitude of downward force applied during penetration, the depth of penetration, the applied torque and the strength of the shaft are varied to adjust to different soil conditions.



Fig.26,27,28: Screw piles are manufactured using varying sizes of tubular hollow sections. They are installed using earthmoving equipment fitted with rotary hydraulic attachments.

Grillages (fig.29 to 31) Steel grillage foundation consists of steel beams also known as grillage beams which are provided in single or double tiers. In case of double tier grillage foundation, the top tier is laid at right angles to the bottom one. On the other hand, where the soil encountered is soft and is permanently water-logged, building walls can be economically supported by suitably designed timber grillage foundation.

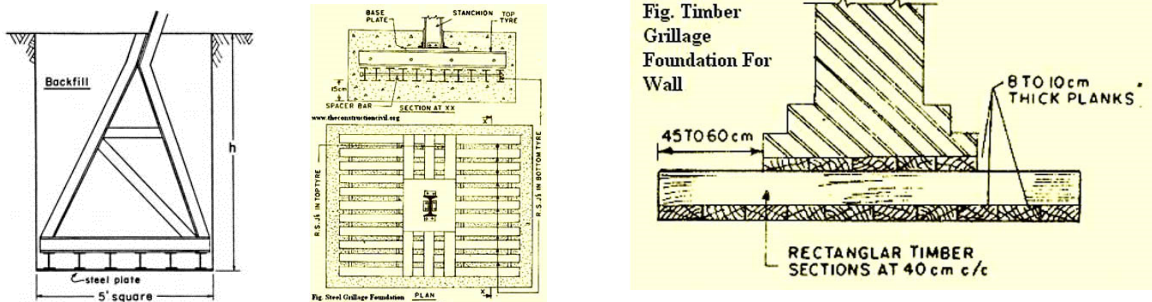


Fig.29,30,31: Grillages are frequently used in transmission tower foundations to avoid concrete.



Fig.32,33,34,35,36: Grouted bars and composite micropiles.

Limitations

Lightweight recoverable foundations are not universally applicable. They are limited by urban planning, the type of building, the geotechnical survey and the contracting methods.

They can be used on all ground suitable for foundations of buildings ranging from one or two storeys (soft ground) to four and five storeys (hard ground) and therefore cover a large proportion of building needs. It is advisable to start by considering **the urban planning** and the geotechnical characteristics of the site in order to avoid the inappropriate solutions that are so common on the outskirts of large cities, as in the Llobregat and Besòs river deltas near Barcelona (figs 37, 38).



Fig.37 San Cosme borough, Llobregat delta. Fig.38 La Mina borough, Besòs delta.

Moreover, common practice of **subcontracting at the lowest price** benefits conventional-well known solutions obviating the overall costs in the short, medium and long term.

Geotechnical surveys and codes

Geotechnical surveys should more accurately determine the mechanical characteristics of the ground to avoid underestimating the resistance of compact, hard and very hard ground because the current regulations allow far higher values than those that are now widely used.



Fig.39,40 Unnecessary pollutant excavation in hard rock due to the application of criteria corresponding to soil.

Rock mass requires characterization based on field investigation methods and techniques different from those used for soils. Compression strength and description of discontinuities are crucial. In the current Spanish code, the bearing capacity is evaluated from the unconfined compression strength, fracture spacing and joint aperture, not applicable to soil. However, most geotechnical surveys do not meet the code and apply tests and formulas corresponding to soils that results in over sizing the excavation, foundations, extra costs and delays (fig.39,40). In addition, conservative criteria applied to bracing in hard soils lead to useless tie beams (fig.41,42).



Fig.41,42 Useless excavation and reinforced tie beams intended to brace the footings in hard rock.

Conclusions

Consideration of the environmental impact of foundations affects not only construction materials and solutions, which are usually already considered in the evaluation methods. It also affects urban planning, the choice of building type for the ground on which it rests, the geotechnical survey that provides the design values, and the contracting methods.

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