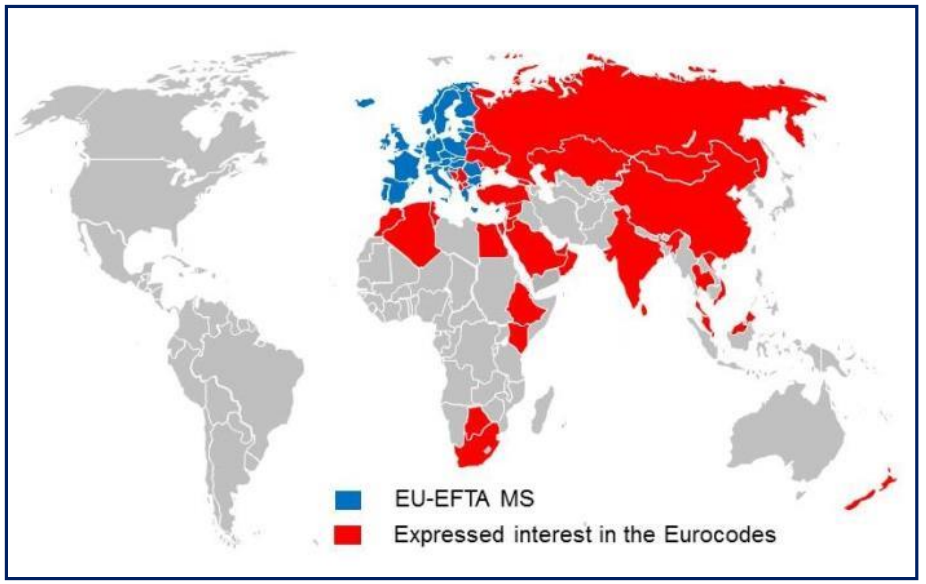
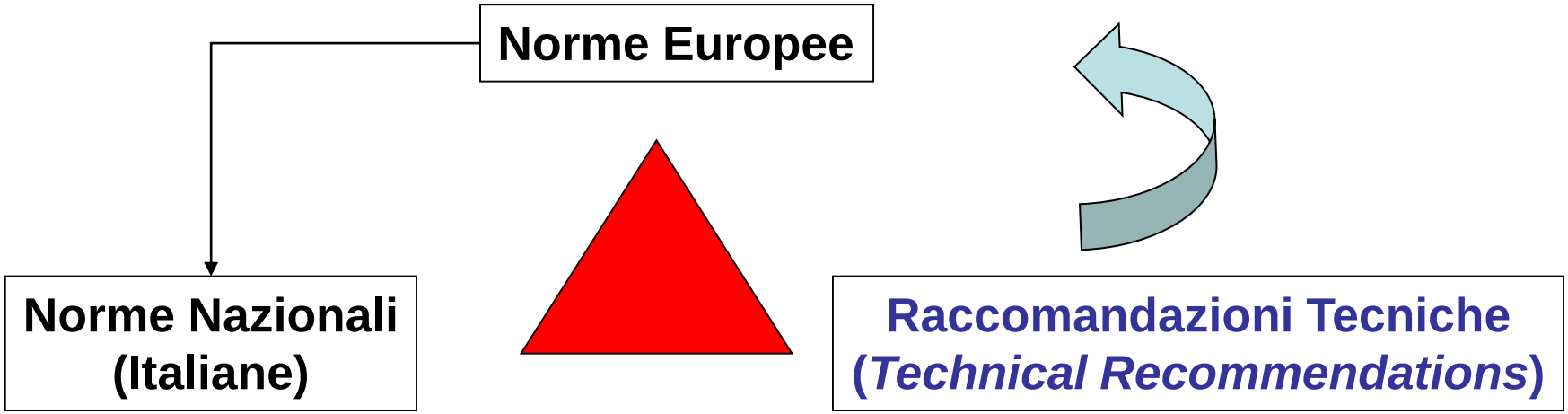
NORMATIVA EUROPEA SUL MIGLIORAMENTO DEI TERRENI

Paolo Croce, Università di Cassino, 10 marzo 2016



QUADRO NORMATIVO



Progetto → **Esecuzione** → **Controllo**

Un processo normativo complesso, in continua evoluzione

Croce., Pane e Scarpelli: Aggiornamenti sull'Eurocodice 7 (febbraio 2015)

nonostante siano trascorsi molti anni da quando il processo di unificazione normativa europeo si è avviato, in molti paesi, tra cui l'Italia, gli Eurocodici non sono ancora entrati nell'uso comune, per ragioni che variano da paese a paese. In Italia il motivo di tale difficoltà è certamente da attribuire al fatto che gli Eurocodici rappresentano una disposizione regolamentare subordinata alle norme Tecniche per le Costruzioni (NTC2008 emanate con il DM Infrastrutture del 14.01.2008). Infatti, sebbene si rifaccia ai principi della norma europea, la norma nazionale è un documento molto diverso perché risponde ad una legge dello Stato che fissa le responsabilità delle figure professionali e di controllo che entrano nel processo costruttivo (dal progetto, alla realizzazione fino al collaudo) e sanziona penalmente il mancato rispetto delle sue prescrizioni. Se quindi da un lato è possibile affermare che progettando con le norme nazionali, il progetto risulterà sostanzialmente in accordo anche con gli Eurocodici, certamente non è mai possibile affermare il contrario. Allo stato attuale dunque, l'uso diretto ed esclusivo degli Eurocodici per la progettazione delle costruzioni in Italia non è consentito, salvo limitatamente ad aspetti non coperti dalla norma nazionale.

NORME TECNICHE COSTRUZIONI (N.T.C.)
14 GENNAIO 2008

Seguono la filosofia delle Norme Europee
(stati limite, valori caratteristici, coeff. parziali, valori di progetto, ecc.)
ma non sono del tutto coincidenti

1. OGGETTO
2. SICUREZZA E PRESTAZIONI ATTESE
3. AZIONI SULLE COSTRUZIONI

4. COSTRUZIONI CIVILI E INDUSTRIALI
5. PONTI

6. PROGETTAZIONE GEOTECNICA

7. PROGETTAZIONE PER AZIONI SISMICHE

8. COSTRUZIONI ESISTENTI

9. COLLAUDO STATICO

N.T.C. 2008: CAP. 6 - PROGETTAZIONE GEOTECNICA

6.1 DISPOSIZIONI GENERALI
6.2 ARTICOLAZIONE DEL PROGETTO
6.3 STABILITÀ DEI PENDII NATURALI
6.4 OPERE DI FONDAZIONE
6.5 OPERE DI SOSTEGNO
6.6 TIRANTI DI ANCORAGGIO
6.7 OPERE IN SOTTERRANEO
6.8 OPERE DI MATERIALI SCIOLTI E FRONTI DI SCAVO
6.9 MIGLIORAMENTO E RINFORZO DEI TERRENI E DELLE ROCCE
6.10 CONSOLIDAMENTO GEOTECNICO DI OPERE ESISTENTI
6.11 DISCARICHE CONTROLLATE DI RIFIUTI E DEPOSITI DI INERTI
6.12 FATTIBILITÀ DI OPERE SU GRANDI AREE

6.9 MIGLIORAMENTO E RINFORZO DEI TERENI E DELLE ROCCE

LE NORME RIGUARDANO: PROGETTAZIONE COSTRUZIONE E CONTROLLO

MA FORNISCONO SOLO CRITERI GENERALI !

- **INDAGINI E CARATTERIZZAZIONE GEOTECNICA**
- **INDIVIDUAZIONE DEI FATTORI GEOTECNICI MODIFICABILI**
- **SCELTA DELLE TECNICHE OPERATIVE**
- **MONITORAGGIO PER VERIFICARE L'EFFICACIA DELL'INTERVENTO**

Che differenza c'è tra Miglioramento e Rinforzo?

NORME EUROPEE E COMITATI TECNICI

Norme Esecutive (Execution Standards)

- EN12715 : Grouting
- EN 14679 : Deep Mixing
- EN14731 : Ground Treatment by Deep Vibration
- EN 12716 : 2001 Jet Grouting
- EN 15237: Vertical drainage

Aggiornamento delle Norme Esecutive:
CEN TC 288 "EXECUTION OF SPECIAL GEOTECHNICAL WORKS"

Norme Progettuali: *Eurocode 7: Geotechnical Design*
Chapter 5.5 - Ground Improvement and Reinforcement

Aggiornamento delle Norme Progettuali:
TC250/SC7 GEOTECHNICAL DESIGN

EUROCODICE 7: SITUAZIONE ATTUALE

(1) investigations

(2) design

(3) control

5.5 Ground improvement and reinforcement

(1)P A geotechnical investigation of the initial ground conditions shall be carried out before any ground improvement or reinforcement method is chosen or used.

(2)P The ground improvement method for a particular situation shall be designed taking into account the following factors where appropriate:

— thickness and properties of the ground or fill material;

— magnitude of water pressure in the various strata;

— nature, size and position of the structure to be supported by the ground;

— prevention of damage to adjacent structures or services;

— if the ground improvement is temporary or permanent;

— in terms of anticipated deformations, the relationship between the ground improvement method and the construction sequence;

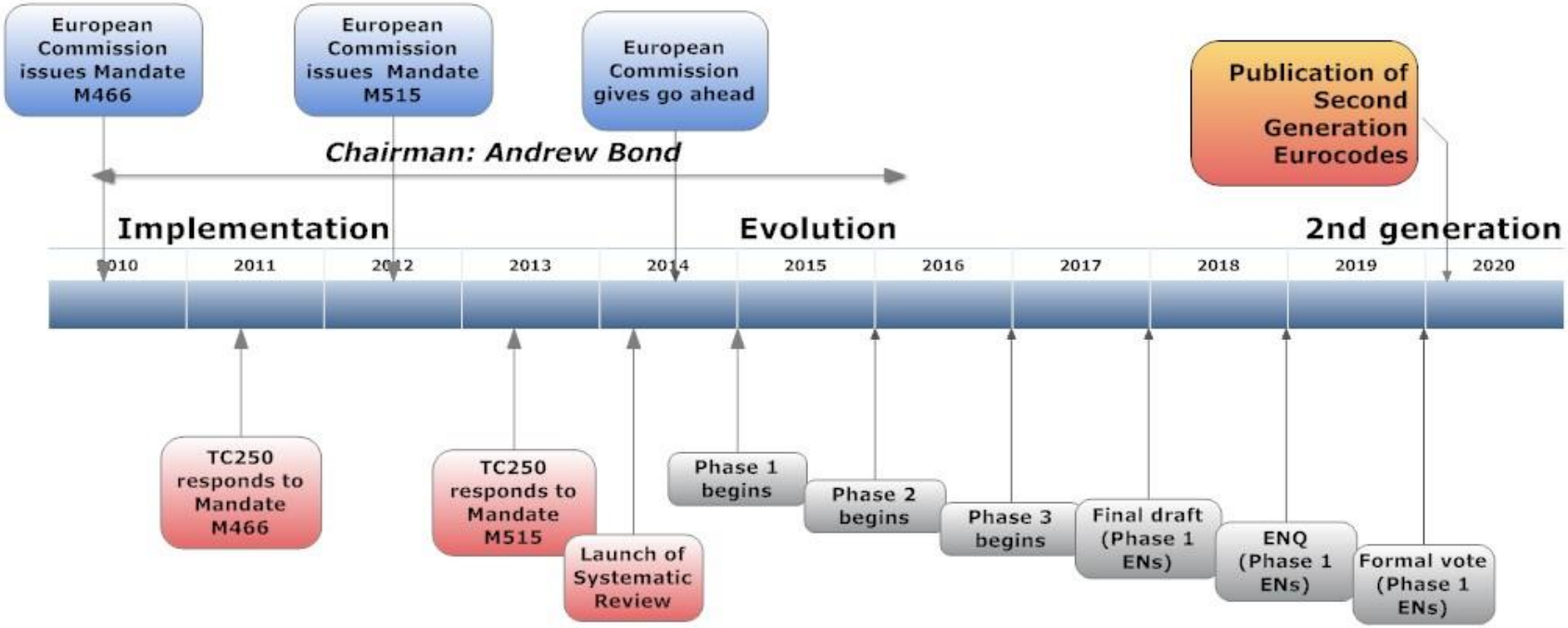
— the effects on the environment including pollution by toxic substances or changes in ground-water level;

— the long-term deterioration of materials.

(3)P The effectiveness of the ground improvement shall be checked against the acceptance criteria by determining the induced changes in the appropriate ground properties.

La norma è molto vaga: come quella nazionale italiana.

Eurocode 7 timeline 2010-2020



Systematic Review of Eurocode 7

1. **Correct** – Do any clauses require editorial or technical correction?
2. **Clarify** – Which clauses would benefit from improvements in clarity?
3. **Add** – Where should the scope of the EN be extended?
4. **Remove** – Where could the EN be shortened?
5. **Make cheaper** – Are there any clauses whose application results in uneconomic construction?
6. **Make easier** – Are there any clauses whose application necessitates excessive design effort?

UNA LUNGA FASE PREPARATORIA: GLI "EVOLUTION GROUPS"

EG/Title		Convenor
0	Management + oversight	Bond (GBR)
1	*Anchors*	*Farrell (IRL)*
2	Ease-of-use	Danilewicz (GBR)
3	Model solutions	Orr (IRL)
4	Numerical methods	Lees (CYP)
5	Reinforced ground	Vanicek (CZE)
6	Seismic design	Scarpelli (ITA)
7	Pile design	Moormann (GER)
8	Harmonization	Bond (UK)
9	Water pressures	Vogt (GER)
10	Calculation models	Vrettos (GER)
11	Characterization	Schneider (SWI)
13	Rock mechanics	Harrison (GBR)
14	Ground improvement	Croce (ITA)

GROUND IMPROVEMENT: NEW CHAPTER

Nella nuova versione dell'Eurocodice 7 si prevedono
2 capitoli distinti su Ground Improvement e Ground Reinforcement

Evolution Group 14: Metodo di Lavoro… (2013)

Which is the border between "G. Improvement" and "G. Reinforcement" ?
- **what do we mean with "Ground Improvement"?**
- **what do we mean with "Ground Reinforcement"?**

FIRST STEP.
Definition of "Ground Improvement"
Several Proposals…
- **change of ground properties**
- **with or without addition of artificial material**
- **to meet specific design requirements**

SECOND STEP.
Collection of Information on G.I. techniques :

- **G.I. typical applications**
- **G.I. existing rules – recommendations**
- **G.I. main effects**

Technique	France	Germany	Italy	Poland	Romania	Turkey	U.K.
GROUTING (permeation, compaction, etc.)	X	X	X	X	X	X	X
JET GROUTING	X	X	X	X		X	X
DEEP MIXING	X	X	X	X			X
DEEP VIBRATION (Vibrated Stone - Sandy Columns)	X			X	X		X
DYNAMIC COMPACTION (Tamped Gravel - Sandy columns)	X			X			X
RIGID INCLUSIONS (VIBRATED)	X			X			
RIGID INCLUSIONS (BORED)	X			X			
BLASTING				X			
STABILIZATION with bindings (lime, cement, etc.) for earthworks	X	X	X	X		X	X
GROUND FREEZING	X		X				
VERTICAL DRAINAGE	X		X	X	X	X	X

FREQUENT USE OF GROUND IMPROVEMENT TECHNIQUES

TECHNIQUE	CEN EXECUTION STANDARDS	NATIONAL RULES OR RECOMMENDATIONS
GROUTING (permeation, compaction, etc.)	EN 12715 (Grouting)	GERMANY*
JET GROUTING	EN 12716 (Jet Grouting)	GERMANY* ITALY**
DEEP MIXING	EN 14679 (Deep Mixing)	GERMANY*
DEEP VIBRATION (Vibrated Stone - Sandy Columns)	EN 14731 (Ground Treatment by Deep Vibration)	FRANCE**
DYNAMIC COMPACTION (Tamped Gravel - Sandy columns)		FRANCE**
RIGID INCLUSIONS (VIBRATED)		FRANCE**
RIGID INCLUSIONS (BORED)		FRANCE**
BLASTING		
STABILIZATION with bindings (lime, cement, etc.) for earthworks	EN 14227. (Hydraulically bound mixtures)	GERMANY**
GROUND FREEZING		
VERTICAL DRAINAGE	EN 15237 (Vertical Drainage)	

EXISTING STANDARDS, RULES, TECH. RECOMMENDATIONS ON GROUND IMPROVEMENT TECHNIQUES.

*National Standard on Design
** Recommended practice on design, execution and quality control

TECHNIQUE	Foundations	Retaining Structures	Embankments	Tunnels and Excavations	Dams and Reservoirs
GROUTING (permeation, compaction, etc.)	X			X	X
JET GROUTING	X	X		X	X
DEEP MIXING	X	X			
DEEP VIBRATION (Vibrated Stone - Sandy Columns)	X				
DYNAMIC COMPACTION (Tamped Gravel - Sandy columns)	X		X		
RIGID INCLUSIONS (VIBRATED)	X		X		
RIGID INCLUSIONS (BORED)	X		X		
BLASTING	X				
STABILIZATION with bindings (lime, cement, etc.) for earthworks			X		
GROUND FREEZING				X	
VERTICAL DRAINAGE	X		X		

MAIN APPLICATIONS OF GROUND IMPROVEMENT TECHNIQUES

1.5.2.3
ground
soil, rock and fill in place prior to the execution of the construction works;

TECHNIQUE	SOIL CEMENTATION	SOIL DENSIFICATION	DRAINAGE
GROUTING (permeation, compaction, etc.)	X		
JET GROUTING	X		
DEEP MIXING	X		
DEEP VIBRATION (Vibrated Stone or Sandy Columns)		X	X
DYNAMIC COMPACTION (Tamped gravel and sandy columns)		X	X
RIGID INCLUSIONS (VIBRATED)		X	X
RIGID INCLUSIONS (BORED)		X	X
BLASTING		X	
STABILIZATION with bindings (lime, cement, etc.) for earthworks	X		
GROUND FREEZING	X		
VERTICAL DRAINAGE			X

MAIN EFFECTS OF GROUND IMPROVEMENT TECHNIQUES

CEMENTATION: cohesion increase (+ permeability decrease)
DENSIFICATION: friction angle increase
DRAINAGE: permeability increase

THIRD STEP. Design Approaches ??

A) Diffused Ground Improvement

Typical Techniques:
- Grouting
- Deep Vibration
- Dumping
- Blasting
- Stabilization
- Ground Freezing

1. Evaluate: Change of Ground Properties
2. Define: Improved Characteristic Values

Follow standard design procedures

B) Creation of a "Structural Element"

Provided with well defined:
- Geometry
- Mechanical Properties

Typical Techniques:
- Jet Grouting
- Deep Mixing

Develop specific Design Rules

TC250/SC7 - EG14 – Ground Improvement

FINAL REPORT

DRAFT October 28th 2015

1. General → 1.3 Terms and Definitions
2. Classification of Actions
3. Actions and Design Situations
4. Design Methods and Design Considerations
5. Monitoring and Control

Appendix on Inclusions

EG14 Draft Final Report (2015)

In the **current EN 1997**, the clauses of interest for EG14 are listed in **section 5.5: "Ground Improvement and Reinforcement"**. It is a very short section that does not provide any useful information and should be entirely rewritten, by making **two new chapters** respectively on "**Ground Improvement**" and on "**Ground Reinforcement**".

It is pointed out that Ground Improvement can be used for nearly all geotechnical applications such as:

- Foundations
- Retaining structures
- Slopes, cuttings and embankments
- Water control

It will be thus particularly important to cross-check the chapter on Ground Improvement with all the other chapters of the Eurocode.

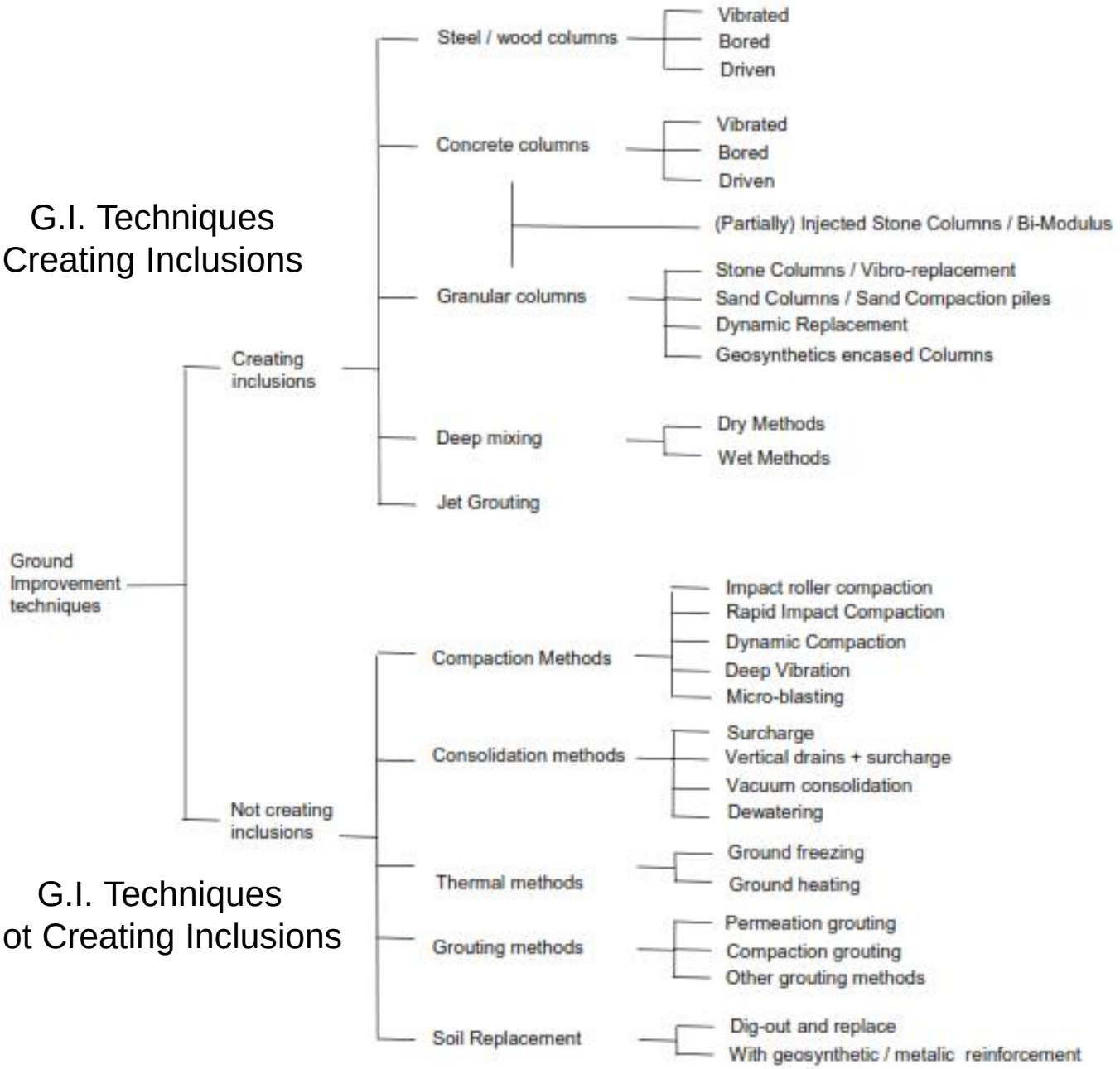
TERMS AND DEFINITIONS

- Ground Improvement (G.I.) is defined as: "the modification of ground properties in order to bring the effects of actions within ultimate and serviceability requirements"
- G.I. can be achieved by binding and/or densifying the ground and/or filling voids and/or creating inclusions in the ground.

- An Inclusion is any discrete element created in the ground, physically disconnected from any structure, provided with prescribed geometry and mechanical properties.
- A Rigid Inclusion is defined as an inclusion made of material significantly stiffer than the surrounding soil and having measurable unconfined compressive strength.

- Discrete G.I. is defined as a G.I. where inclusions which are created in the ground remain separated from the surrounding ground.
- Diffused G.I. is defined as a G.I. where the ground can be modelled as a homogeneous material to be described by a single set of parameters.

G.I. Techniques
Creating Inclusions



G.I. Techniques
Not Creating Inclusions

FOUNDATIONS ON RIGID INCLUSIONS

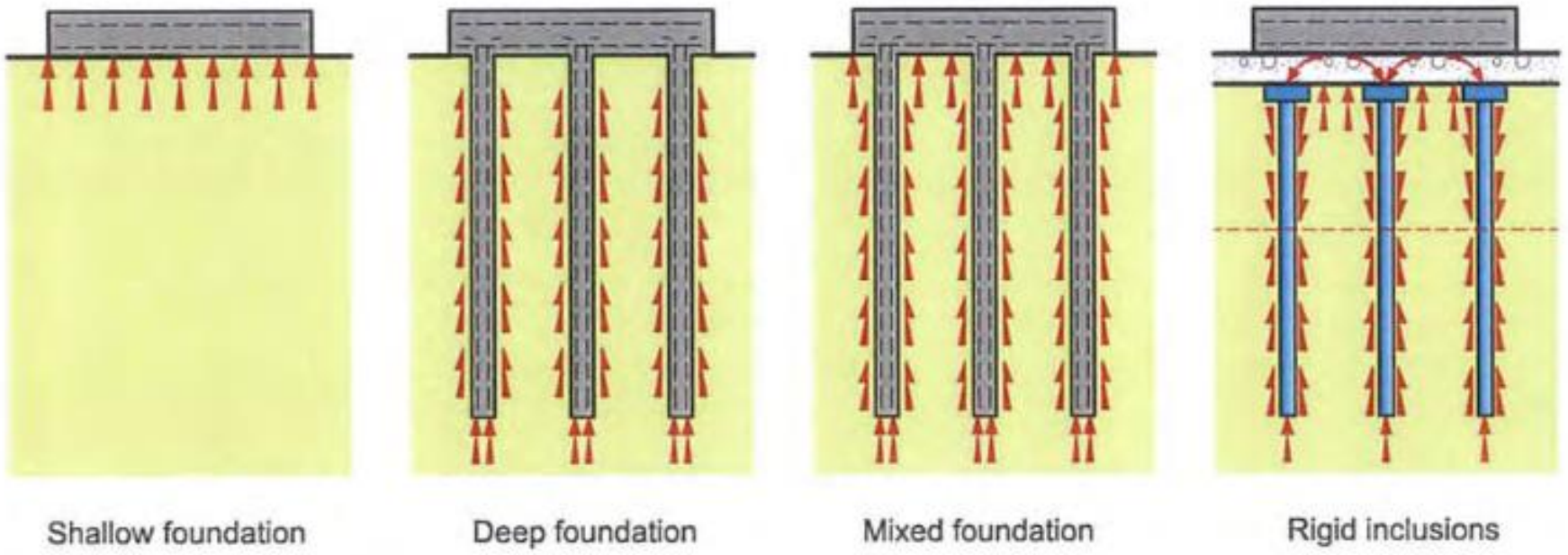


Figure 1.1: The various types of foundations.

ASIRI NATIONAL PROJECT – FRANCE 2005 - 2011

LOAD TRANSFER PLATFORM: UN DIBATTITO IN CORSO

- Load transfer platform is defined as a stratum positioned between the discrete G.I. and the structure, to provide load transfer and/or to modify its distribution as required for the design.

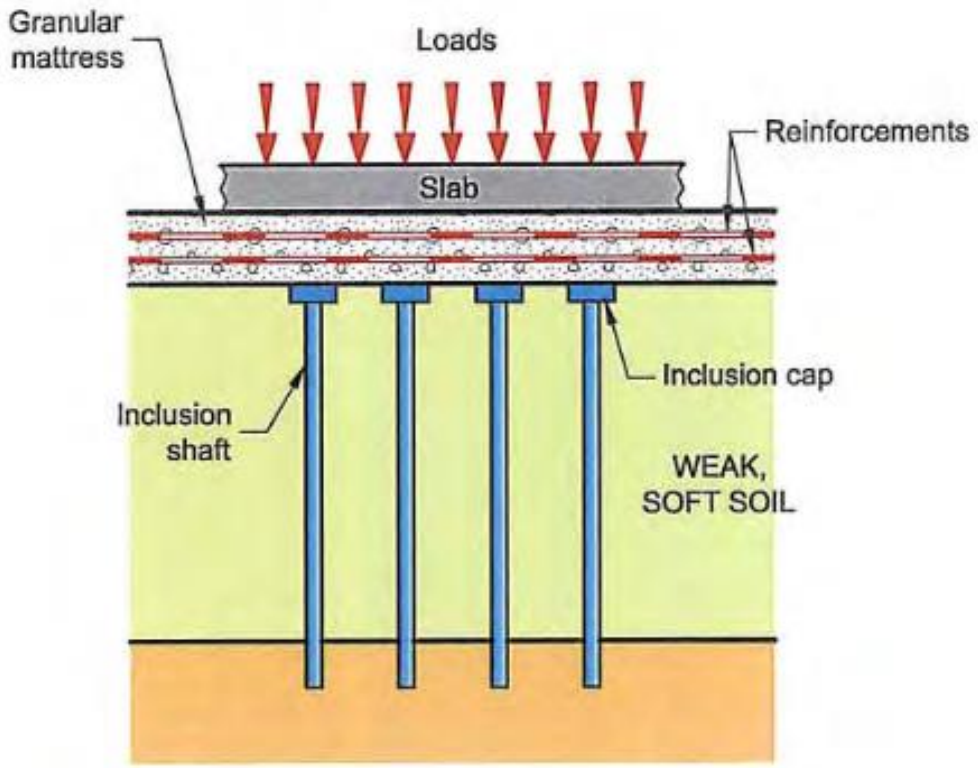


Figure 1.2: The four components of a complete foundation on rigid inclusions.

ASIRI NATIONAL PROJECT – FRANCE 2005 - 2011

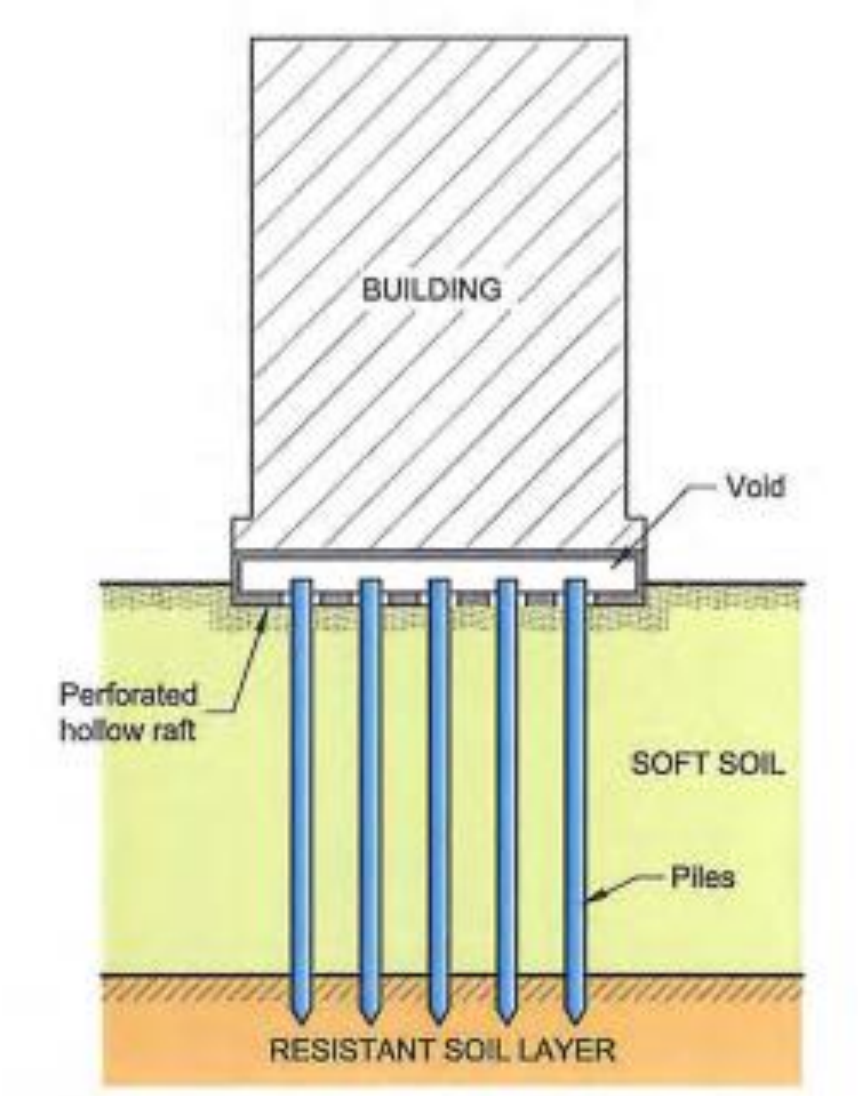


Figure 1.6: Inclusions independent of the supported structure (Mexico).

ASIRI NATIONAL PROJECT – FRANCE 2005 - 2011

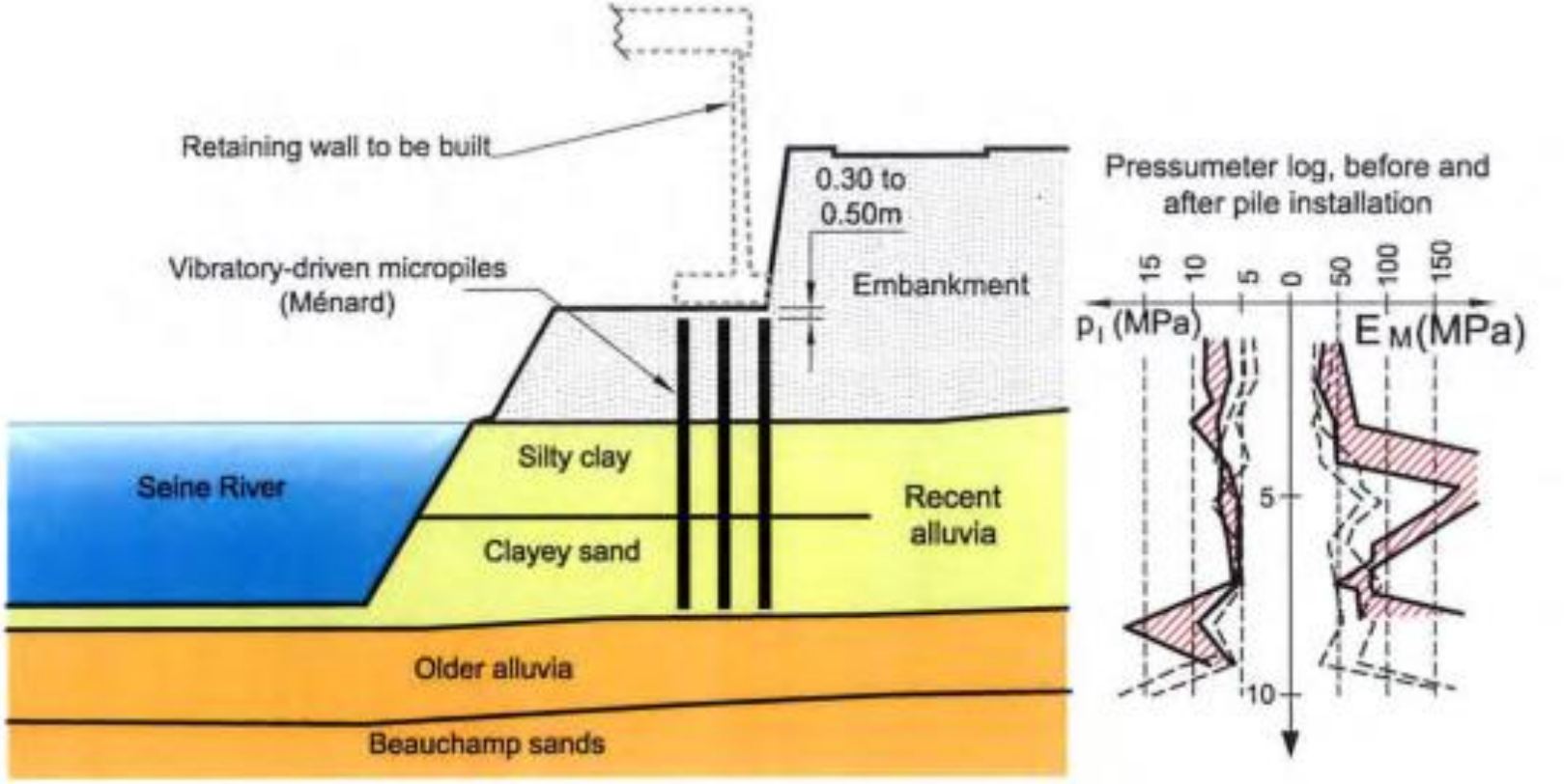


Figure 1.7: Improvement in foundation soil characteristics thanks to the installation of piles (France).

ASIRI NATIONAL PROJECT – FRANCE 2005 - 2011

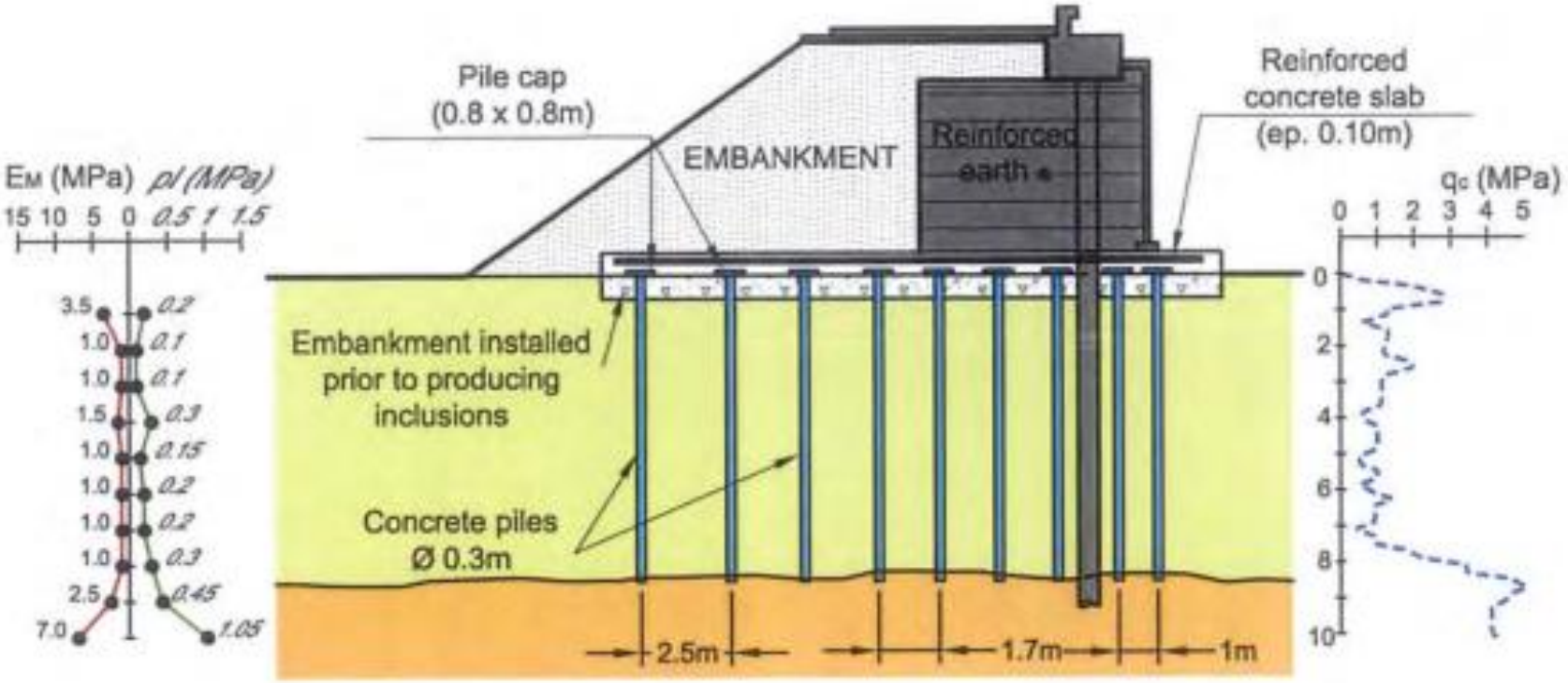


Figure 1.9: Carrère junction abutment (Martinique).

ASIRI NATIONAL PROJECT – FRANCE 2005 - 2011

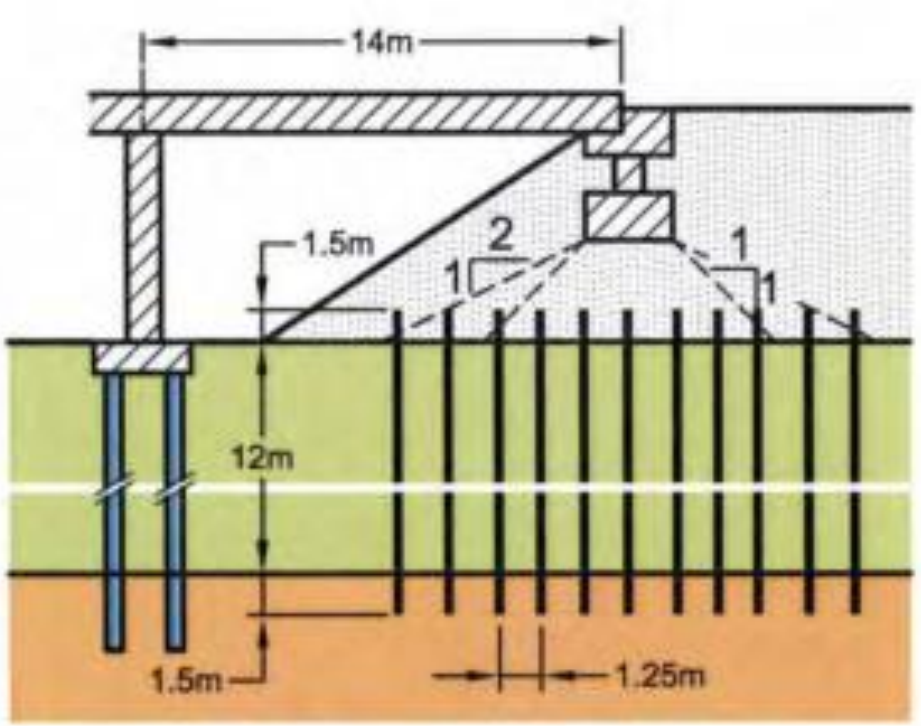


Figure 1.10: Abutment and embankment on rigid inclusions for the A43 motorway section, Chambéry (France).

ASIRI NATIONAL PROJECT – FRANCE 2005 - 2011

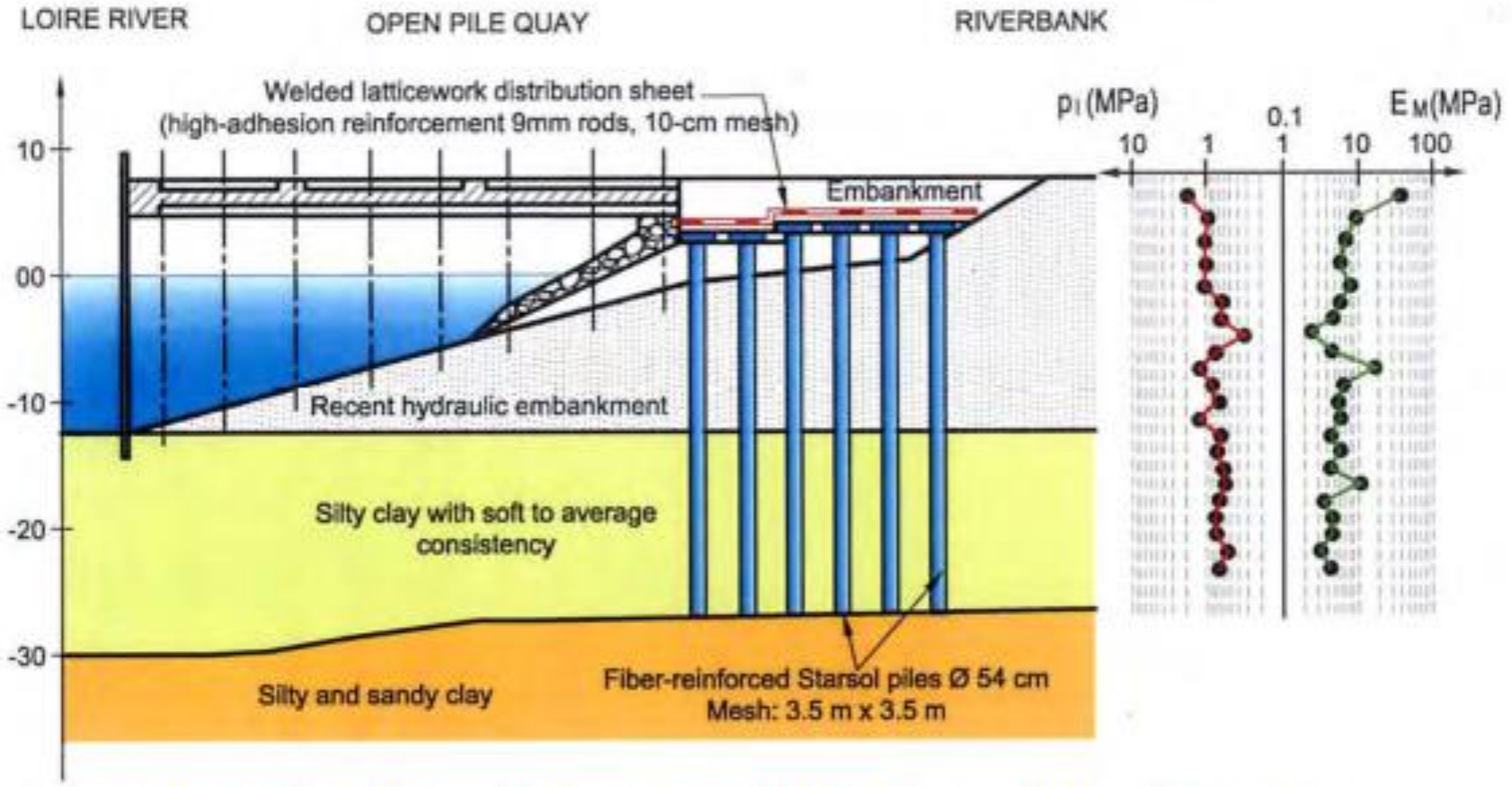


Figure 1.11: Transition zone on inclusions between a dock on piles and the riverbank (Montoir-de-Bretagne, France).

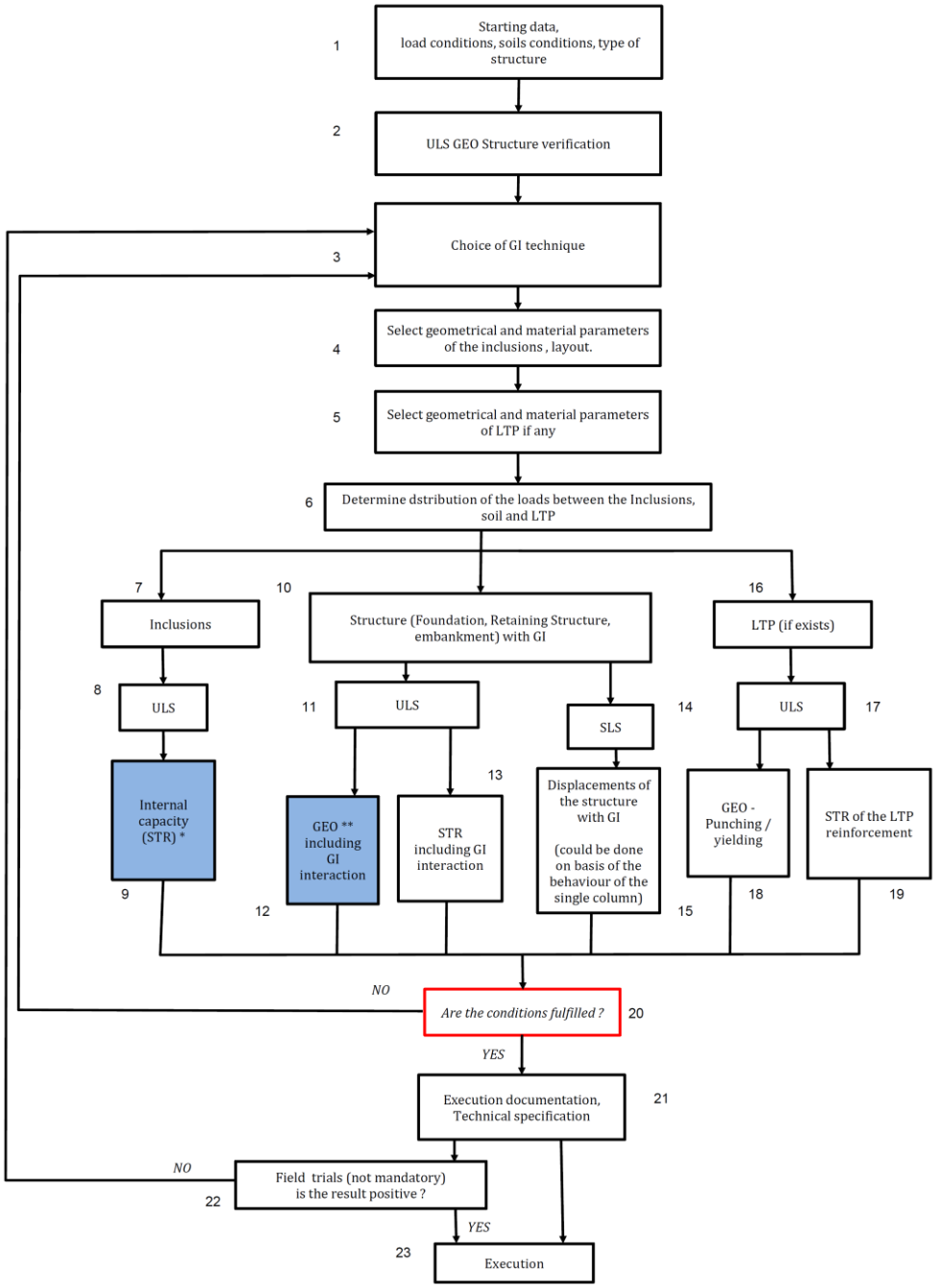
GROUND IMPROVEMENT DESIGN METHODS

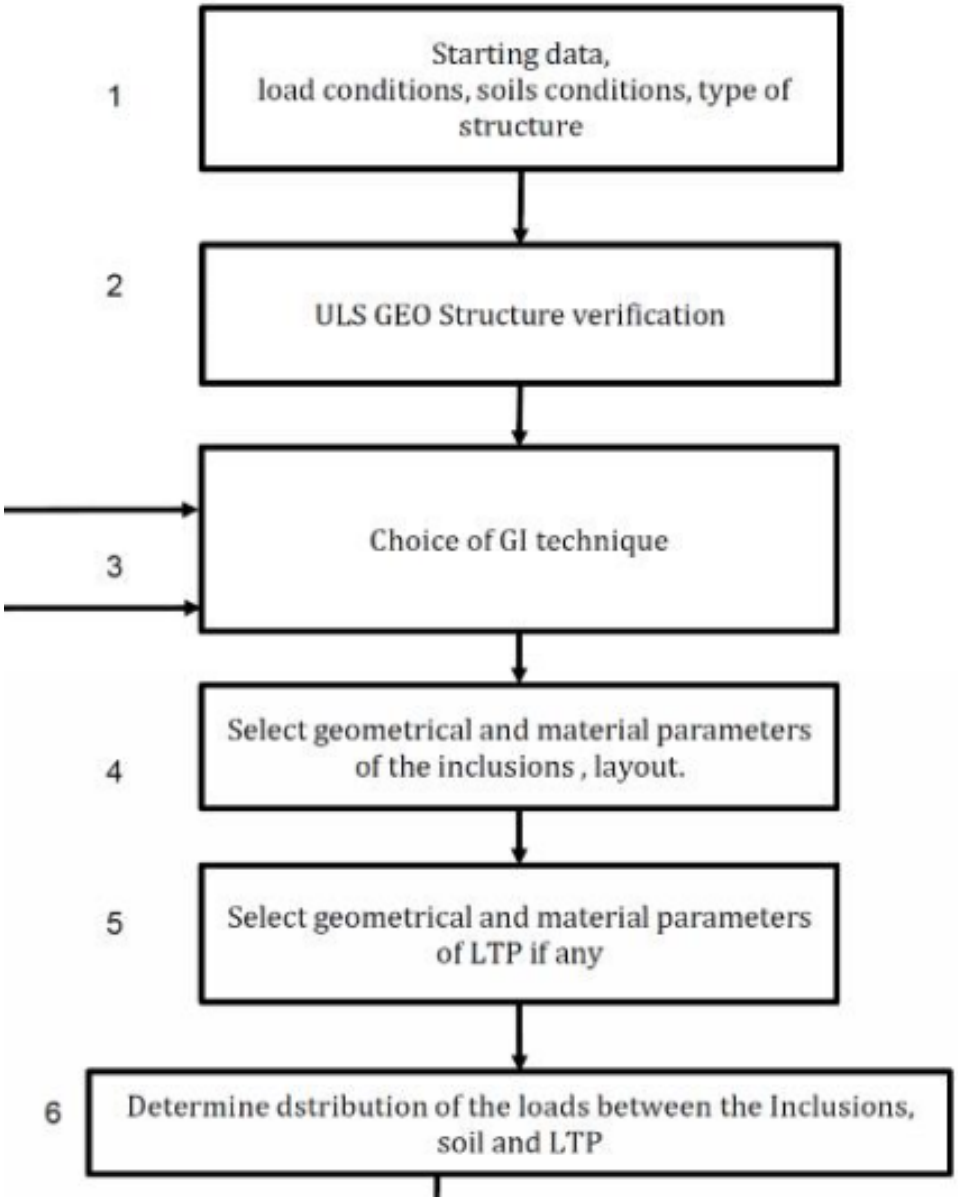
- DIFFUSED
- DISCRETE

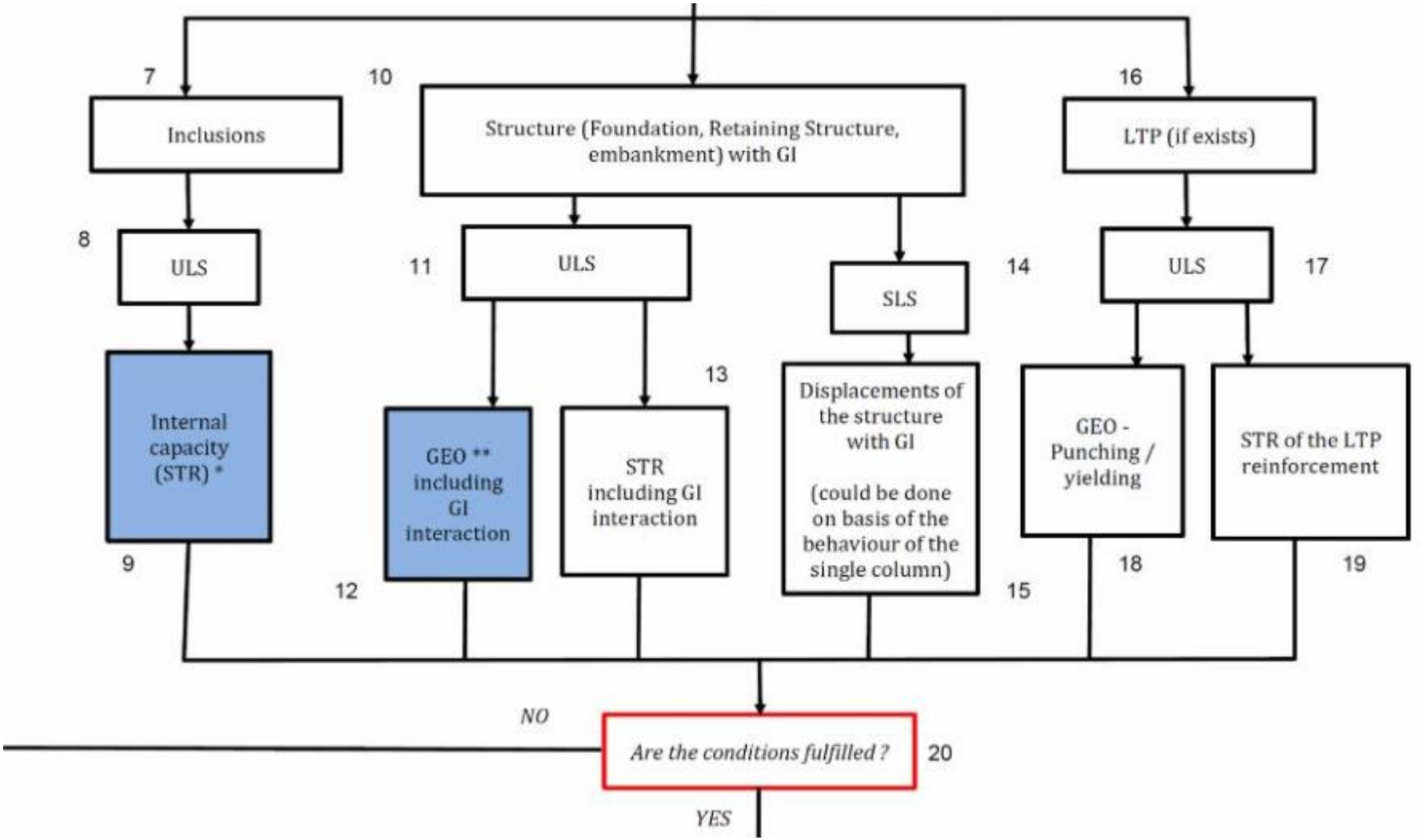
Design of Diffused Ground Improvement. This design method is applicable when the behaviour of the improved ground can be conveniently modelled by conventional soil or rock models. In order to follow this method, the designer should evaluate the change of ground properties (i.e. cohesion, friction angle, permeability, etc.) and should consequently define the "Improved Characteristic Values" for the material properties. In such case, design rules for foundations, retaining structures, embankments, slopes etc. are applied according to the relevant sections of the Eurocode. The Improved Characteristic Values are evaluated using testing, empirical methods, comparable experience or analytical/numerical modelling.

Design of Discrete Ground Improvement. This design method can be applied when ground improvement relies on inclusions. The overall performance of the improved ground is calculated by considering separately the characteristics of the inclusions, the soil/rock and their interaction. In such case, design rules for foundations, retaining structures, embankments, slopes etc. are applied according to the relevant sections of the Eurocode 7. The addition of a load transfer platform may be required. (Detailed considerations and rules are given in the appendix on inclusions.)

EG14 APPENDIX ON INCLUSIONS




1
Starting data,
load conditions, soils conditions, type of structure
2
ULS GEO Structure verification
3
Choice of GI technique
4
Select geometrical and material parameters of the inclusions , layout.
5
Select geometrical and material parameters of LTP if any
6
Determine dstribution of the loads between the Inclusions, soil and LTP


7
Inclusions
8
ULS
Internal capacity (STR) *
9
10
Structure (Foundation, Retaining Structure, embankment) with GI
11
ULS
GEO ** including GI interaction
12
13
STR including GI interaction
SLS
14
Displacements of the structure with GI
(could be done on basis of the behaviour of the single column)
15
16
LTP (if exists)
ULS
17
GEO - Punching / yielding
18
STR of the LTP reinforcement
19
NO
Are the conditions fulfilled ?
20
YES

FIELD TRIAL (CAMPO PROVE)