# The VVER 1000 and 1200 prestressing system

# Presentation

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FREYSSINET INTERNATIONAL

**Part 1 : The FREYSSINET Group**

**Part 2 : Prestressing for nuclear vessels**

- **2.1 Bonded prestressing**
- **2.2 Unbonded prestressing**
- **2.3 Summary of different solutions**

# Part 1 :

# The FREYSSINET Group

**The First name of FREYSSINET & Cie was STUP. This company was created in 1943, by Eugène FREYSSINET who invented prestressing in 1928.**

**This company was named FREYSSINET in 1976**

**To day Freyssinet is a 100% subsidiary of the VINCI Group which is the largest construction group in the world with a 2009 turnover of**

**33 500 Millions Euros**

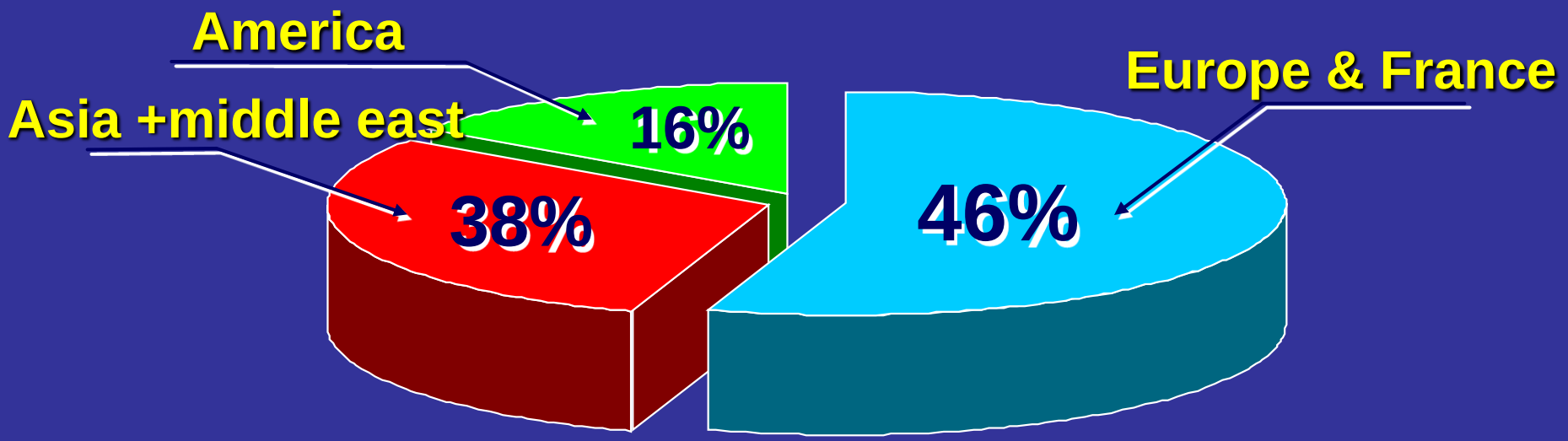
**Eugéne FREYSSINET ( 1879 – 1962)**

FREYSSINET

- More than 100 subsidiaries in the world
- 5200 staff & labour force in 2009

| | |
|---|---|
| 850 Executives | = 16% |
| 1 450 technicians | = 28% |
| 2 900 manual workers and staff employes | = 56% |

- A 560 Millions Euros € turnover in 2009

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# WORKS

**FREYSSINET,**
**Construction high tech company :**

- **Construction**
- **Repairs - maintenance**

# WORKS

## Cable structure : stay cable

- Bridges : more than 80 bridges in the last 10 years
- 70% of the world market

Normandie Bridge (France)

Cape girardeau (USA)

Charles River bridge
BOSTON (USA)

Rion Antirion Bridge (Grece)

Cooper river bridge (USA)

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# WORKS

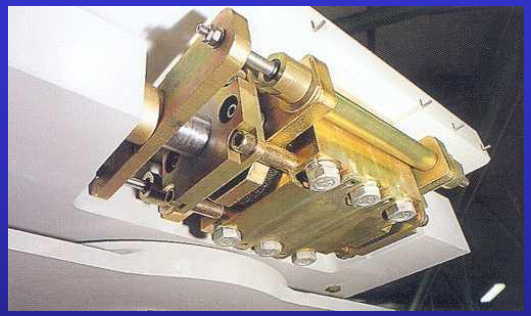
➔ Construction

## Bridges products

Bridges Expansion joints



Bridges Bearings



Para-sismic devices

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# WORKS



## Construction methods

**Freyssinet developped efficient and cost saving construction methods as well as their relazted activities :**

- Heavy lifting/ jacking
- Incremental launching
- Deconstruction
- Precasting
- Casting-in-situ

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# WORKS



## HEAVY LIFTING and JACKING

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# WORKS

## Prestressing

- Bridges
- Offshore platforms
- Nuclear reactors
- LNG tanks
- Silos
- Buildings


e


Silos and LNG tanks

## ➔Construction

### Freyssinet, world leader for prestressing


European Parlement Building

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**Freyssinet has supplied the prestressing system for 143 nuclear containment vessels in the world**


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**Daya-Bay,Ling-Ao,Hong-Ya-He,Ning-De, Yiang-Jiang, Fang-Chen-Gang :**
**22 NPP 900Mw PWR (China)**

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# CHINA - Qinshan candu Phase III
# 2 PHWR x 700Mw

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# Civaux NPP (France)
# 2 x 1500 Mw  N4 Type

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# TIANWAN(ex Lianyungang) NPP(China)
# 2 x 1000Mw VVER 1000


**500 Anc 55 C 15**

**2700tons strand T 15.7**

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# KUDANKULAM NPP (India)
# 2 VVER 1000Mw

- 514 Anchorages 55 C 15
- 2750tons of HPDE coated strands T 15.7

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# OLKILUOTO N°3 (Finland)
# EPR 1600Mw

- **540 Anchorages 55 C 15**
- **31 000lm of ducts 160mm**
- **2250Tons of strands T15.7 class 1860Mpa**

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# FLAMANVILLE 3 EPR (France)
# 1 EPR 1600Mw

- **540 Anchorages 55 C 15**
- **31 000lm of ducts 160mm**
- **2250Tons of strands T15.7 class 1860Mpa**

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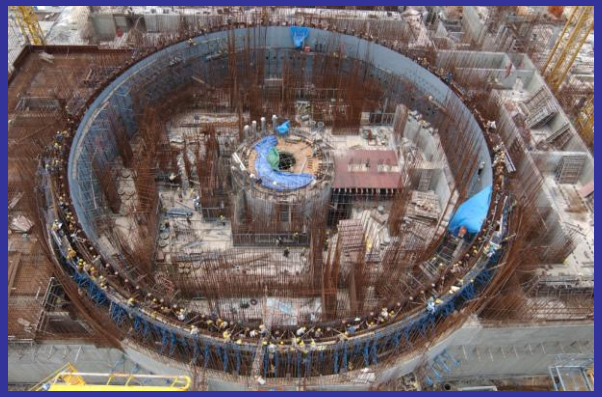
# The 55 C 15 Freyssinet prestressing system has been used for :

2 vessels VVER 1000 at Tianwan in China

2 vessels VVER 1000 at Kudankulam in India



The OL3 EPR in Finland

The Flamanville EPR in France

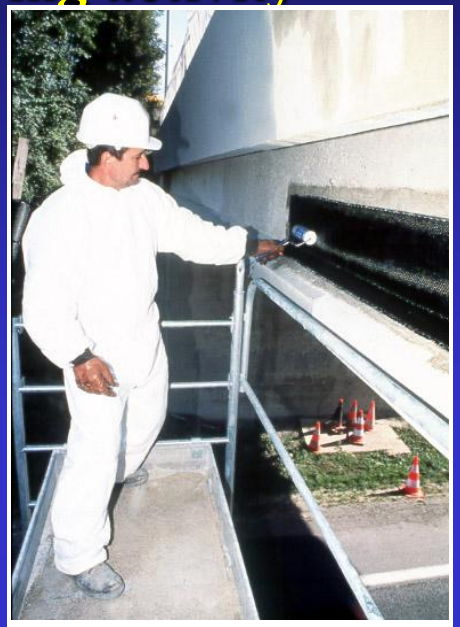
2 EPR in Taïshan China

# WORKS

## → Repairs et maintenance

### Repair works: a fast growing activity

- Structural reinforcing
- Material treatment
- Protection
- Assessment
- Repair of historical monuments



Fiber carbon

Additional Prestressing

Shotcrete

Cathodic Protection

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KUWAIT – Bubiyan Bridge

VIETNAM - Pont de Saigon

KOSOVO : Mitrovica Bridge

EUROPE 1 Radio Building

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# Part 2 :

# Prestressing for nuclear vessels

## 2. 1 Bonded prestressing

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## 1 PROCESS:

1. The ducts and the embedded parts of anchorages are placed into the formworks during the containment construction
2. Once the containment is fully concreted, the strands are threaded into the ducts and tensioned .
3. Once tensioned , cement grout are injected into the tendons.

## 2 REFERENCES:

The bonded pretressing has been used for all the 58 french nuclear containments as well as for all the 30 chinese nuclear containments and also for the 4 EPR containments under construction in Finland, France and China.

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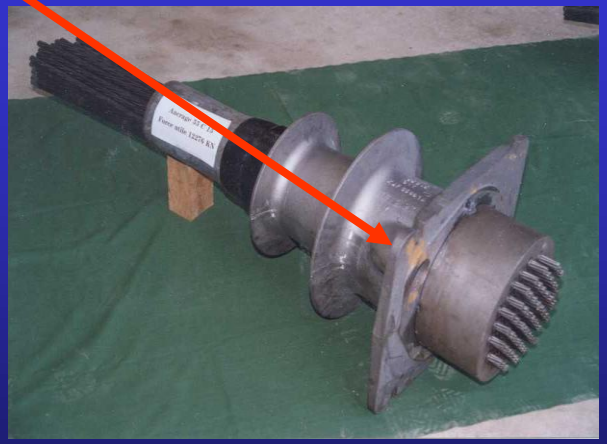
# Selection of the prestressing tendons

A prestressing tendon is made of:

- a duct
- a tendon
- two anchors

Placing of 55 T 15 ducts in prefabricated reinforcement



Each component must de chosen according to the designer requirements

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**LFC (Low friction) Flexible corrugated sheet for horizontal tendons**

**Rigid steel pipe for vertical tendons**

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# Tendon tensioning

**55 T 16 Horizontal tendons tensioning**

**55 T 16 Vertical tendon tensioning**

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# Cement grout fabrication

## Mixing plant

## Remixing tank


## Turbo mixer

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# Dynamometers

- Tendons could be fitted with dynamometers

- These tendons are grouted with petroleum wax


Heating Tank (10m3) with pump

Insulated & heating hoses

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# 2.2 Unbonded prestressing for VVER 1000 and 1200 vessels

## with greased & HPDE coated strands

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## 1 PROCESS:

1. The ducts and the embedded parts of anchorages are placed into the formworks during the containment construction
2. During the containment construction, strands are threaded into the ducts and cement grout is injected between strands .
3. Once the containment is fully concreted, the strands are tensioned .

## 2 REFERENCES:

This kind of unbonded pretressing is used for the Kudankulam NPP under construction in India, for the Kalinine unit 4 and for the replacement of wires tendons on Novovoronej 5 and Kalinine 1.

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# Greased HPDE coated strands injected with cement grout before tensioning

**This prestressing system is used for the wires tendons replacement on VVER 1000 first generation as well for the Kalinine 4**

**96 Helicoïdal tendons 46 C 15**

**Average lenght = 177ml**

**36 looped dôme tendons 46 C 15**

**Average lenght = 108ml**

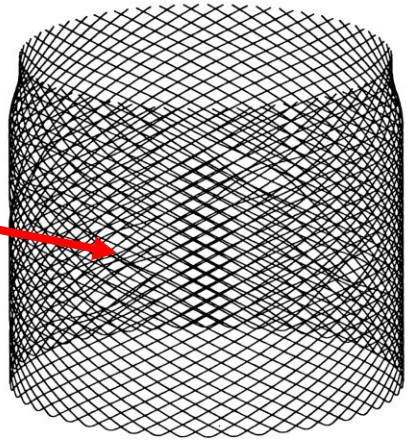

Figure 2 : câblage VVER hélicoïdal du cylindre de l'enceinte
(une seule nappe, soit un câble sur deux, est représentée ici)

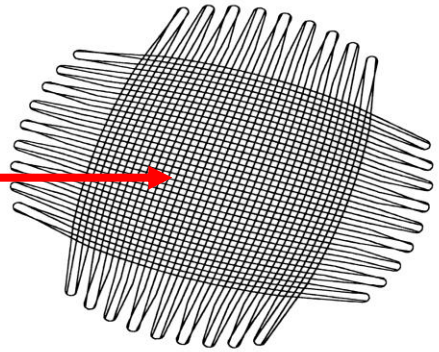

Figure 3 : câblage VVER en U du dôme de l'enceinte



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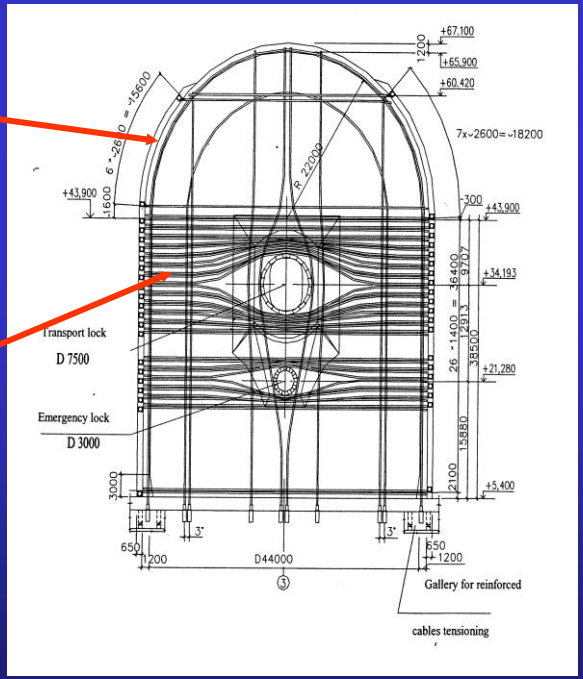
# Greased HPDE coated strands injected with cement grout before tensioning

**This prestressing system is used for the two VVER 1200MW containments which are under construction for the Kudankulam Nuclear plant in India .**

**60** **inverted U tendons 55 C 15**

**68** **horizontal looped tendons 55 C 15**



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# Greased HPDE coated strands injected with cement grout before tensioning

**Tendons are made of several greased and HPDE coated strands**

**The strand itself is a bright strand, which is greased and HPDE coated**





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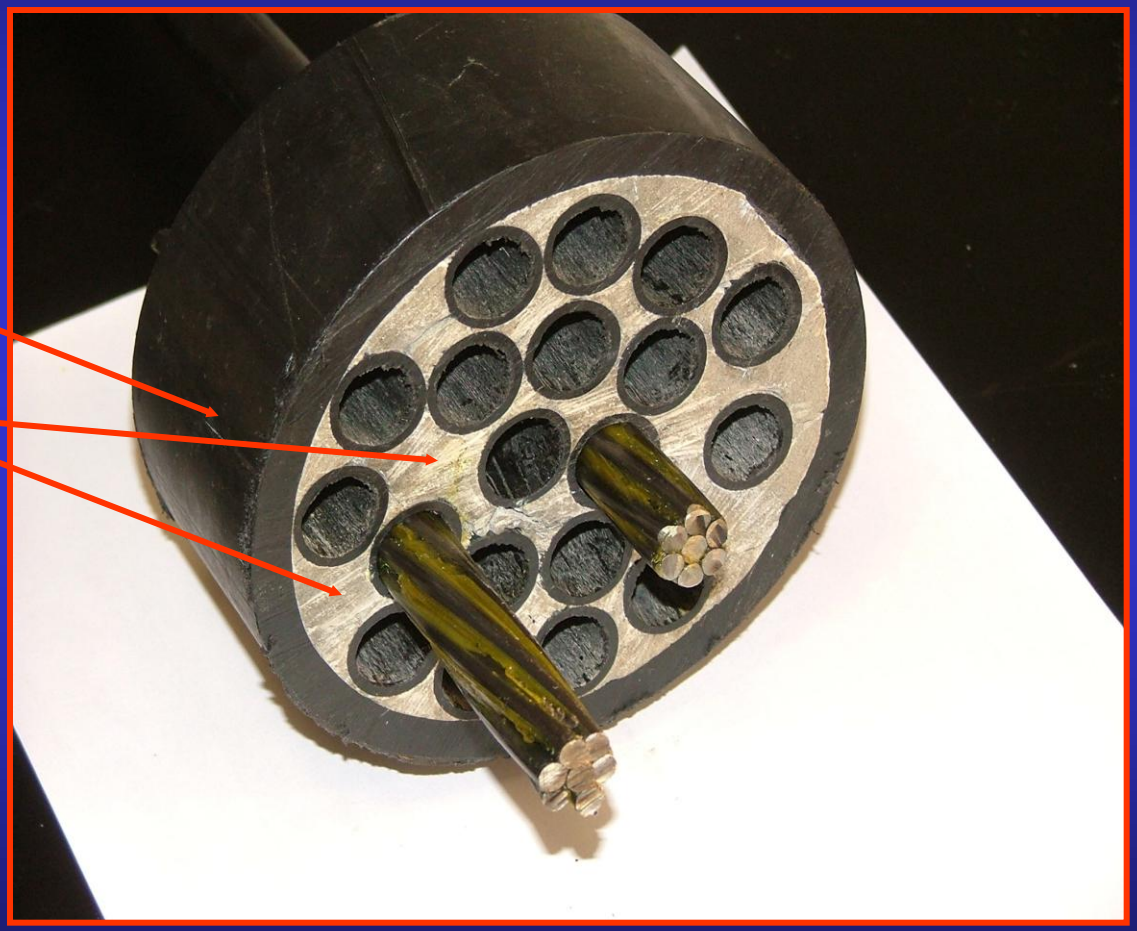
# Greased HPDE coated strands injected with cement grout before tensioning

**The HPDE strands are placed one by one into a duct .**

**Cement grout is injected between the strands. These remain free to move into their individual sheet**





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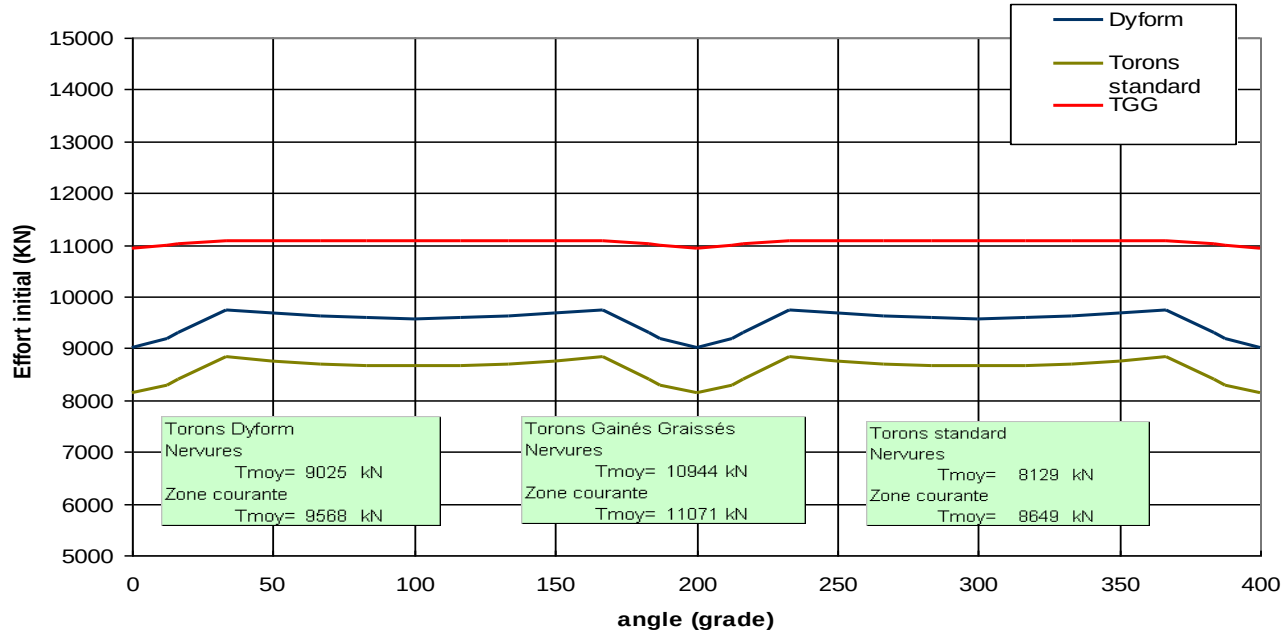
# Case 2 : Greased HPDE coated strands injected with cement grout before tensioning

**The main advantages of this system for nuclear containments are:**

- **An increased and more efficient spreading of prestressing thanks to a very low friction coefficient ( f= 0.05 instead of 0.18 for bright strands)**



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# Strands Threading

**Strands are threaded by pulling with winches and shuttle**



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Mock up for helicoïdal tendons

Kudankulam :Mock up for horizontal tendons

Mock up for inverted U tendons

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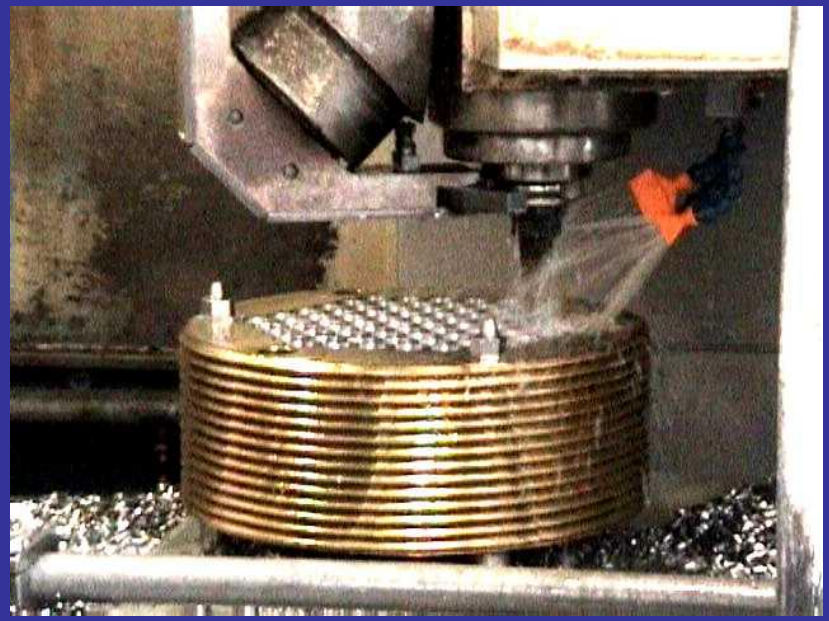
# 3.3) Anchor-blocks and wedges :

**FREYSSINET is manufacturing its own anchorages in its factory PPC located in France near Chalons/Saone**

**Wedges manufacturing**



**Anchors blocks drilling**

## TESTING:

**FREYSSINET has its own testing department where Static and Dynamic tests and miscelaneous test on anchorages components are carried out**



**FREYSSINET 2000Tons Bed test**

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# Tendons are tensioned simultaneoustly at both ends

**55 T 16 Inverted U tendon tensioning**

**55 T 16 Horizontal tendons tensioning**

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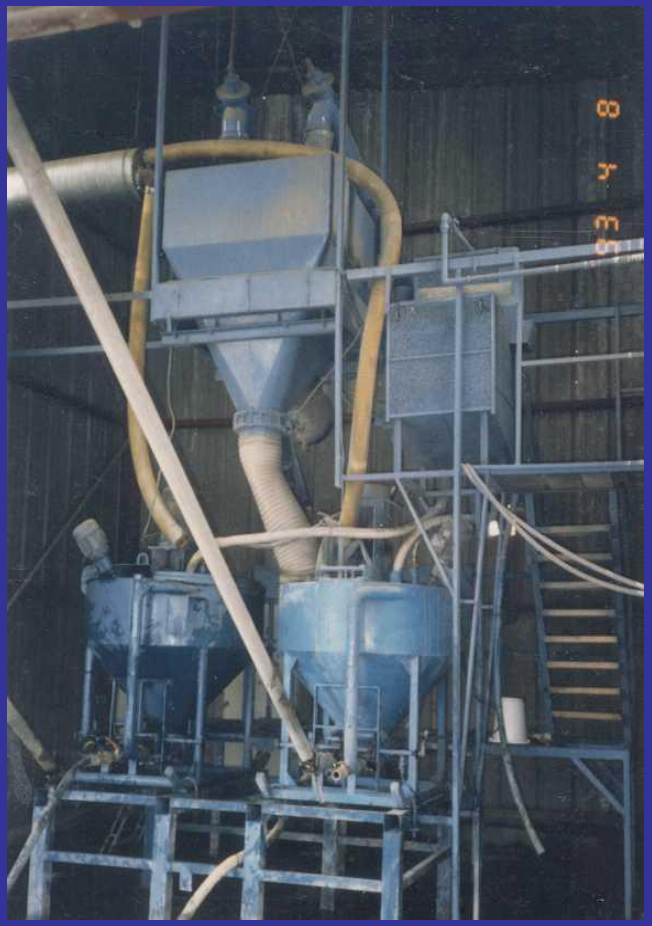
## Retarded-remixed cement grout manufacturing:

## The cement grout is manufactured in a grout manufacturing plant



Mixing plant

Remixing tank

Turbo mixer

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**Injection mock-up**



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# 2.3 Summary of the different solutions

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# ADVANTAGES

| Bonded Prestressing | Unbonded Prestressing (Greased HPDE cStrands) |
|---|---|
| 1. Ducts sizes smaller | 1. Measurable |
| 2. Strands cheaper | 2. Restresseable |
| | 3. Detensionable |
| | 4. Replacable |
| | 5. Planning shorter |
| | 6. Corrosion protection very high |
| | 7. Friction coefficient lower ( f=0,05) |
| | 8. Injection easier |
| | 9. Equitenion not necessary |
| | 10. Save tendons quantity |
| | 11. Short planning for tendons installation |

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# INCONVENIENTS

| Bonded Prestressing | Unbonded Prestressing (Greased HPDE cStrands) |
|---|---|
| 1. Not Measurable | 1. Ducts size bigger |
| 2. Not Restresseable | 2. Strand costly |
| 3. Not Detensionable | 3. Without internal liner, vessel tightness bad in case of loca |
| 4. Not Replacable | |
| 5. Friction coefficient high( f = 0,18) | |
| 6. Difficulty for injection | |
| 7. Planning for tendons installation longer | |
| 8. Necessity to use equitension | |

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# CORROSION PROTECTION LEVEL

| Bonded Prestressing | Unbonded Prestressing (Greased HPDE cStrands) |
|---|---|
| Normal ★ ★ | Very High ★ ★ ★ |

# COST

| Bonded Prestressing | Unbonded Prestressing (Greased HPDE cStrands) |
|---|---|
| Normal ★ ★ | Normal ★ ★ |

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# CONTROLLABILITY

| Bonded Prestressing | Unbonded Prestressing (Greased HPDE cStrands) |
|---|---|
| 0 % | 100% ★ ★ ★ |

# PLANNING of TENDONS INSTALLATION

| Bonded Prestressing | Unbonded Prestressing (Greased HPDE Strands) |
|---|---|
| 9 months ★ | 4 months ★ ★ ★ |

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# Thank you for your attention

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