



UNDERGROUND WORKS

Tunnels

CARENQUE TUNNEL

PORTUGAL

CARENQUE TUNNEL INTEGRATED IN THE A9 CREL (LISBON OUTSIDE RING MOTORWAY)

Client:

Bento Pedroso Construções,
SA

**Preliminary Design/Final
Design and Technical
Assistance:
1993/95**

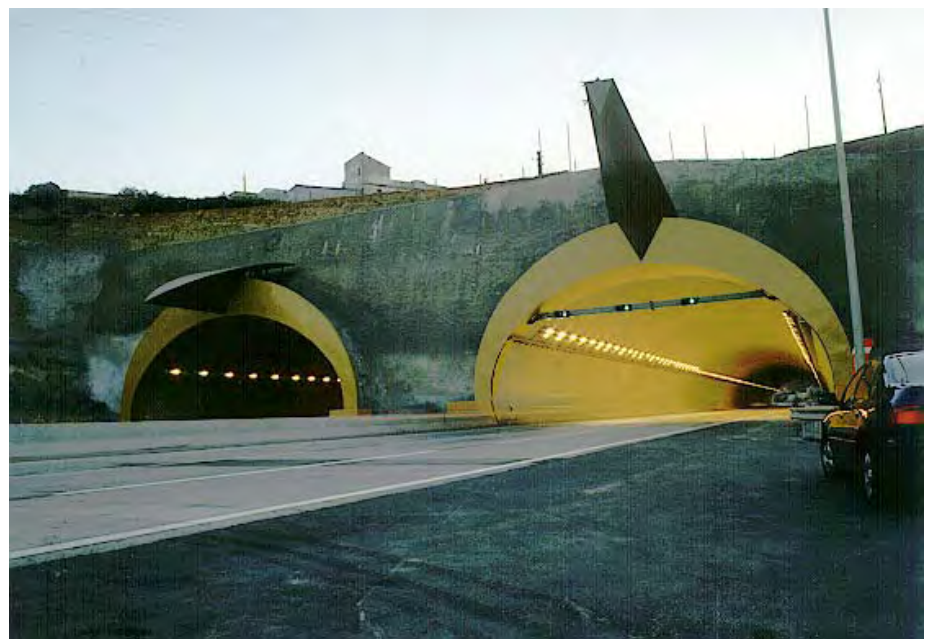
Investment Cost:

11.500.000,00 Euro

Integrated in the Queluz-Pontinha Radial of the A9-CREL, Estádio Nacional-Alverca, the Carenque tunnels were constructed in order to cross an area with Dinosaur footprints from the Cretacic Period.

MAIN CHARACTERISTICS

- Length: 2 tunnels, 265 m each
- Minimum overburden: 2 m
- Maximum overburden: 25 m
- Width of each tunnel: 19.44 m
- Width of piles between the tunnels: 8 m
- Inner area: 143.26 m²
- Outer area: 172.89 m²
- Geological conditions: limestones and marls from the Cretacic Period, a gradient of 10-20° South
- Cross section
 - . maximum height: 8.44 m
 - . number of carriageways: 3 x 3.80 m + a bench of 4 m
- Longitudinal profile: gradient of 0.658%



South Portal



UNDERGROUND WORKS

Tunnels

RAMELA TUNNEL

PORTUGAL

**RAMELA TUNNEL
INTEGRATED IN THE IP2
HIGHWAY – GUARDA /
BENESPERA SECTION
(within the Concession of
SCUT Highway Sections in
the Beira Interior Region)**

Client:
ACESTRADA, ACE
(Group of Contractors)

**Design-and-Build
Tender Design:**
1998

**Final Design and
Technical Assistance to the
Construction:**
1999/2000

Investment Value:
7.500.000,00 Euro

DESCRIPTION:

The layout of the IP2 Highway runs at mid-slope along the Ribeira Teixeira stream valley and tunnel aims at crossing a salient spur in the valley's slope, thus minimising the excavations to carry out.

- Total length: 332 m and 306 m
- Distance between galleries: 22 m with 8 m vertical slippage
- Maximum overburden: 35 m
- Outer area of section: 89,60 m²
- Inner area of section: 74,20 m²
- Gabarit: 8,5 m x 4,7 m
- Section: circular with an internal radius of 5,41 m and straight walls
- Number of carriageways: 2 x 3,5 m
- Longitudinal profile: grade line with a gradient of 4,4%
- Construction method: NATM (New Austrian Tunnelling Method)
- Geological conditions: Porphyritic coarse-grain granite massif, with hydrothermal alteration.





UNDERGROUND WORKS

Tunnels

GARDUNHA IA TUNNEL

PORTUGAL

**GARDUNHA IA TUNNEL
INTEGRATED IN THE IP2
HIGHWAY
(within the Concession of
SCUT Highway Sections in
the Beira Interior Region)**

Client:
ACESTRADA, ACE
(Group of Contractors)

**Design-and-Build
Tender Design:**
1998

**Final Design and
Technical Assistance to the
Construction:**
1999/2003

DESCRIPTION:

The Gardunha IA is integrated in subsection Alcaria / Soalheira of the IP2 Highway. It crosses the Gardunha Mountain Range in a North-South direction.

CHARACTERISTICS:

- Total length: 1 603 m
- Maximum overburden: 235 m
- Construction method: NATM (New Austrian Tunnelling Method)
- Excavation sections: 90 m²
- Widening : 115 m²
- Emergency galleries: 1 for vehicles, 4 for pedestrians





UNDERGROUND WORKS

Tunnels

TUNNEL INTEGRATED IN THE NEW WESTERN ACCESS ROAD TO THE FUNCHAL PORT

Madeira, PORTUGAL

TUNNEL INTEGRATED IN THE NEW WESTERN ACCESS ROAD TO THE FUNCHAL PORT

Client:

SREST – Secretaria Regional do Equipamento Social e Transportes - Madeira.
Direcção Regional de Estradas

Preliminary Study and Final Design:
2002 / 03

Technical Assistance:
2003/06

Investment Cost:
15.400.000,00 Euro

The Western Access Road to the Funchal Port comprises a new road that extends throughout an urban environment with vigorous topography, requiring the construction of a tunnel resorting to drilling techniques.

This tunnel is approximately 600 m long, has a 30 m maximum overburden and a section of 84 m².

In addition to the limitations imposed by the road layout, the design of the gallery took into consideration a road clearance of 8,0 x 4,7 m (LxH) and a typical cross-section with a 8,0 m carriageway (2x3,5 m and 2x0,5 m shoulders) and walkways.

Due to the fact that the tunnel is inserted in an urban area, great importance was given to the restrictions inherent to the interaction between the construction and operation of the tunnel and the quality of life of the populations that inhabit the area.





UNDERGROUND WORKS

Tunnels

BARRAÇÃO TUNNEL

PORTUGAL

BARRAÇÃO TUNNEL INTEGRATED IN THE IP2 HIGHWAY – GUARDA / BENESPERA SECTION (within the Concession of SCUT Highway Sections in the Beira Interior Region)

Client:
ACESTRADA, ACE
(Group of Contractors)

**Design-and-Build
Tender Design:**
1998

Final Design:
1999/2000

**Technical Assistance to the
Construction:**
2001/2003

Investment Cost:
6.500.000,00 Euro

DESCRIPTION:

The Barração Tunnel is located in the IP2 Highway - Guarda-Benespera Section, between PK 7+070 and 7+425, at the beginning of the Northern area of the Ribeira da Teixeira stream valley, along which the layout runs.

Its construction is due to the need of crossing the terminal zone of that valley that suddenly ends, to the plateau at North, without creating a physical barrier that would "isolate" the Barração and Panóias municipalities, respectively at West and East of that road.

The work is formed of two-twin galleries, open by the "cut-and-cover" method, and 355 m long.

- Total length: 355 m
- Maximum overburden: 25 m
- Net area of section: 61.9 m²
- Gabarit: 8.5 m x 4.7 m
- Section: circular
- Number of carriageways: 2 x 3.75 m
- Longitudinal profile: vertical curve with a 14000 m radius
- Construction method: "cut-and-cover"
- Geological conditions: porphyritic and coarse-grain geometric massif, very weathered in the first metres at the surface.





UNDERGROUND WORKS

TUNNELS

GARDUNHA II TUNNEL

PORTUGAL

GARDUNHA II TUNNEL INTEGRATED IN THE IP2 (TRUNK ROAD) BETWEEN THE GARDUNHA I TUNNEL AND SOALHEIRA

Cliente:

Junta Autónoma de Estradas
(JAE)
(Portuguese Road Directorate)

**Detailed Design and Final
Design:**
1994/95

**Technical Assistance to
Construction:**
1999/01

Investment Cost:
6.000.000,00 Euro

CHARACTERISTICS OF THE TUNNEL

- Total length: two parallel galleries, 320 m long each
- Maximum overburden: 250 m
- Area: 82 m²
- Geological conditions: saturated highly weathered granites in the portals and fairly good rock conditions in the tunnel intermediate zone.
- Cross section:
 - . maximum height – 6,80 m
 - . available area inside the tunnel – 57 m²
 - . number of carriageways – 2 x 3,75 m
- Construction Method: NATM (New Austrian Tunneling Method)

DESCRIPTION

The Gardunha II tunnel, constituted by two parallel galleries, 320 m long each, was excavated under a southern counterfort of the Gardunha mountains, included in the Variant 3 alternative developed in order to minimise the negative environmental impact of the highway over the Alpedrinha historical town.





UNDERGROUND WORKS

Tunnels

GARDUNHA I TUNNEL

PORTUGAL

GARDUNHA I TUNNEL INTEGRATED IN THE IP2 (TRUNK ROAD) BETWEEN FUNDÃO AND ALPEDRINHA

Client:

Junta Autónoma de Estradas
(JAE)
(Portuguese Road Directorate)

**Detailed Design and Final
Design:**
1992/94

**Technical assistance to the
supervision:**
1994/97

Investment Cost:
18.000.000,00 Euro



*Northern Portal
(Construction Phase)*

CHARACTERISTICS OF THE TUNNEL

- Total Length: 1 525 m (unidirectional gallery)
- Maximum Overburden: 245 m
- Area: 82 m²
- Geological conditions: granites in the portals and metamorphic rocks in the tunnel intermediate zone
- Cross Section:
 - . maximum height: 6,80 m
 - . available area inside the tunnel: 57 m²
 - . number of carriageways: 2 x 3,75 m
- Longitudinal Profile: Grade line with 1,7% constant ascending gradient, followed by a convex curve close to the portal

DESCRIPTION

Integrated in the Deviation to the EN 18 between Fundão and Alpedrinha, the tunnel crosses the Gardunha Mountains, following a north-south direction.



Northern Portal



UNDERGROUND WORKS

Tunnels

VAROSA TUNNEL

PORTUGAL

VAROSA TUNNEL INTEGRATED IN THE TRUNK ROAD Nº 3 (IP3)

Client:

Junta Autónoma de Estradas
(Portuguese Road Directorate)

Tender Design:

1992/93

**Final Design /
Technical Assistance:**

1995/98

Investment Cost:

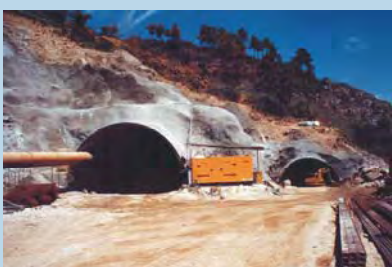
3.500.000,00 Euro

TECHNICAL DATA:

- Total Length: 2 galleries with 380 m and 340 m
- Distance between galleries: 12 to 25 m
- Maximum overburden: 80 m
- Area: 80 m² each gallery
- Number of carriageways: 2 x 3,5 m
- Longitudinal profile: grade line with a gradient of 4,4%
- Construction method: NATM (New Austrian Tunneling Method)
- Geological conditions: generally granites of fine particles with schists occurring in the area of the south portal

DESCRIPTION:

Integrated in the IP3 between Régua and Reconcós, the tunnel crosses the left abutment of the Varosa arch dam with a height of 76 m. The weir of the galleries is located about 26 m above the elevation of top of dam and at a minimum distance of about 130 m. The left abutment of the dam was subject to important repair works in 1984 and 1985, namely its consolidation, and therefore the construction of the tunnel implied a tight vibration control in the body and foundation of the dam.





AMBIENTE

SLOPE STABILISATION AND RETAINING STRUCTURES

SLOPE STABILISATION OF RN 379-1 BETWEEN OUTÃO AND PORTINHO DA ARRÁBIDA

PORTUGAL

SLOPE STABILISATION OF RN EN 379-1 BETWEEN OUTÃO AND PORTINHO DA ARRÁBIDA

Client:

EP – Estradas de Portugal,
EPE

Basic Design:

2004 / 2005

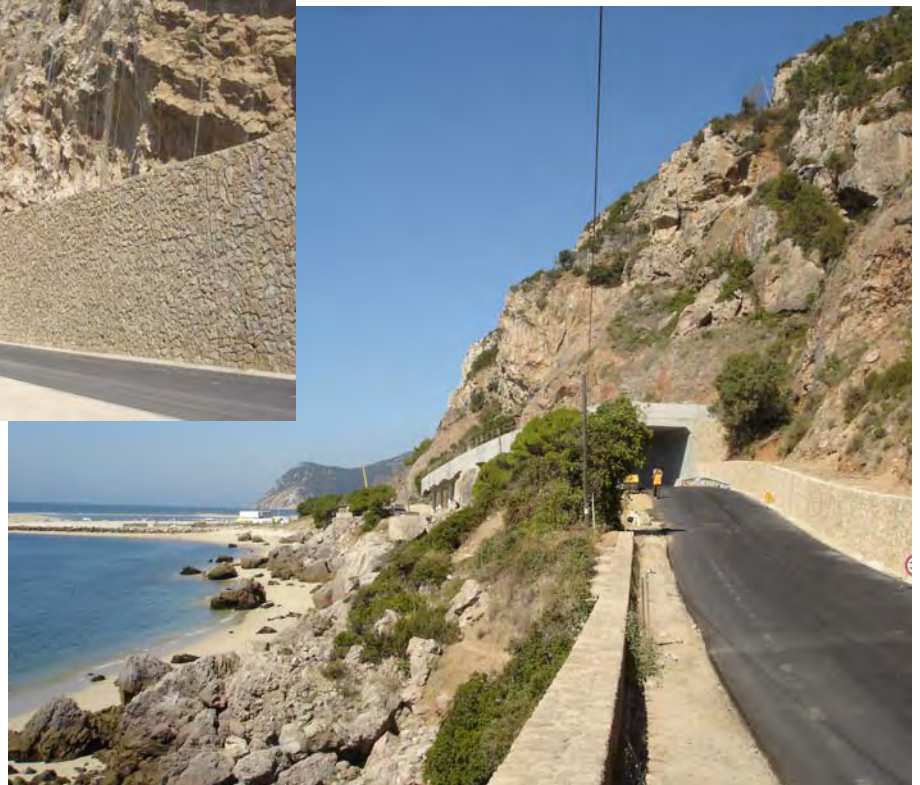
**Technical Assistance to the
Construction Works
undertaken under a Design –
Build Project**
2005 /2006

The EN379-1 road is located in the foot of the Arrábida Mountains, whose higher point reaches the El.501m. The intervention area for the slope stabilization is between Outão and Portinho of Arrábida, for almost 4 km.

The road is an axis of great importance for touristic use of the Natural Park of Arrábida, the whole year round, with larger seasonal incidence in the course of the summer, for access to the beautiful beaches of the area.

The geological and geotechnical conditions of the natural hillside have been provoking the permanent occurrence of fall of rock blocks to the road, situation worsened by the accentuated precipitation and for the fires happened in the Summer of 2004 that eliminated substantial part of the vegetation that helped to sustain the blocks.

Due to serious problems of safety, the road was closed during two years. During this time the design of proper stabilization measures and the construction of the works were completed. Three levels of protection were installed: stiff barrier just near the road, reinforced steel mesh with rock bolts in the main rock outcrops and dynamic barriers of medium to high energy to stop eventual rolling blocks falling from inaccessible slopes.





**PAUTE RIVER
REHABILITATION
PROGRAMME**

Client:
European Union

Technical Assistance:
1996/2000

**Studies undertaken in
Association**

DESCRIPTION

In March 1993, a paramount landslide occurred in "La Josefina" site, on the Paute River, some 20 km from the Cuenca City. As a consequence, a huge dam was created, obstructing the river valley, impounding almost 200 million m³ of water.

The waters began to rise and flooded upstream "La Josefina", seriously endangering the rest of the valley due to the immediate risk of the natural dam's rupture. Given the serious situation, the national authorities decided to excavate an emergency spillway, so as to regulate, as far as possible, the reservoir level and the discharge flow.

At the end of April the water reached the emergency spillway crest and on June 1st the discharged flow rapidly developed giving rise to a regressive erosion process that originated a flood of almost 11.000 m³/s. It destroyed completely the downstream valley, including all bridges, unstabilizing huge land masses from the valley slopes, strongly modifying the valley and the river bed morphology. It is believed that the landslide caused at least 100 casualties, and material losses were estimated at about 150 million dollars (\approx 1% of Ecuador's GDP).

Due to the very complex nature of the "La Josefina" natural disaster, the European Union appointed a group of Consultants, that included COBA, to provide technical assistance to the project.



Initial phase of the slope flattening

The programme effectively began at the end of 1996, COBA having been responsible for the technical assistance pertaining to slope stabilization, erosion control and bridge reconstruction. For this purpose, diagnosis studies of the Paute River Valley slope stability were performed, and a specific study was undertaken for the "La Josefina" slope stabilization, along with similar studies for other large landslides.

Simultaneously, COBA analysed and followed up the bridge, canal and culvert preliminary and final designs, issuing technical reports and studying the road protection works.

COBA also designed the La Josefina permanent bridge located downstream the provisional bridge at the foot of Cerro Tamuga slope.

"La Josefina" Landslide, on the Paute River





LISBON METRO EXTENSION

NICOLA / PIC-NIC / BNU BUILDING IN THE HISTORICAL CITY CENTRE

REINFORCEMENT DESIGNS

Client:

BPC / CBPO / AGROMAN / SOMAGUE / PROFABRIL / ACER ACE

Designs:

1994/96

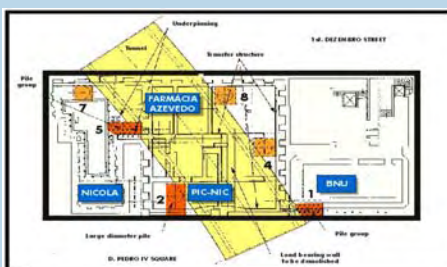
DESCRIPTION:

The Lisbon Metro is extending its lines to the historical city centre. Tunnels were constructed with recourse to a "TMB", interfering with buildings located above the metro alignment. Amongst the buildings identified as being at risk was the Nicola / Pic-Nic / BNU building. This building is located at D. Pedro V Square, and its original construction date remotes to 1837 - 1845, therefore being part of the national heritage stand.

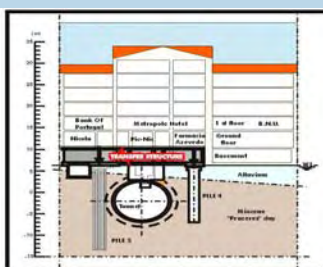
COBA's intervention, within the strengthening of the interfered buildings, was included in the general set of design activities associated to the works. There was a close interface with the tunnel design and construction, which defined the constraints and parameters for the reinforcement designs. We are therefore before a situation where, besides the construction movement occurred at the surface, a physical interference was verified.

The building was strengthened with a new transfer structure at basement level designed to displace its weight to new piling laid outside the tunnel. The principal activities developed by COBA comprised the following:

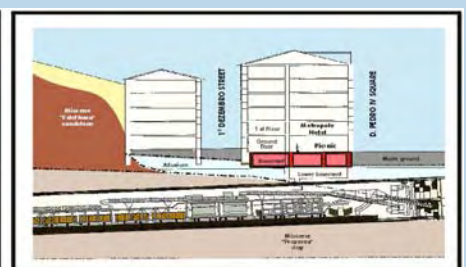
- i) general demolition and excavation;
- ii) pile construction;
- iii) construction of the reinforcement structure, including demolition of wall fends, so as to allow for beam and slab construction;
- iv) demolition of existing walls between the basement and the ground-floor;
- v) load transfer to new foundations by means of hydraulic systems incorporating flat jacks, including instrumentation;
- vi) removal of the physical interference at basement level, comprising the foundation slab, walls and central nucleus;
- vii) monitoring during the TBM passing, followed by final adjustment by reactivating of the hydraulic system.



Transfer structure and foundations



Transfer structure



Tunnel and buildings



**STORM WATER DRAINAGE
TUNNELS IN THE
NORTHERN ACCESS TO THE
FEDERAL CAPITAL AND IN
THE GENERAL PAZ AVENUE
– CILDAÑEZ STORM WATER
TUNNELS.**

CLIENT:

Ministério de Economía y
Obras y Servicios Públicos

**Supervision and Control of
the Works:**
1997/2000

*Activity carried out in
association*

Investment Cost:
31.500.000,00 Euro



*TBM – Shield, for excavation of soils
in urban environment*

UNDERGROUND WORKS

Hydraulic Tunnels

CILDAÑEZ STORM WATER TUNNELS

ARGENTINA

DESCRIPTION

The works aim at collecting the water surpluses in the Arroyo Cildañez basin which converge near the General Paz Avenue, in the stretch comprised between the la Noria Bridge and the Mansilla Avenue, by diverting them through buried pipes towards the Matanza river, in order to systematise the surface drainage of the city of Buenos Aires.

The works comprise the construction of nine stretches of reinforced concrete pipe, in a total length of about 8 km, nearly all in tunnel. This is a very large and extremely complex work, mainly due to the fact of crossing an urban and sub-urban area, composed of granular soils of the Pampeano formation, and thus a special attention was paid to the control of settlements, by using a primary lining with concrete segments and a secondary inner lining with cast in place concrete. On the other side, it was necessary to define policies and strategies aiming at minimising the interferences between the execution of the works and the development of the normal daily life.

CHARACTERISTICS OF THE TUNNEL

- Length: 7 830 m,
- Inner diameter: Ø 4,40 m throughout 6 000 m; Ø 2,80 m throughout 1 830 m
- Overburden: 5 to 12 m
- Construction method: TBM (Tunnel Boring Machine)
- Geological conditions: detrital soils of the Pampeano formation, slightly over-consolidated.

The supervision of works involved five main aspects:

- control of the underground excavation works
- control of the concrete works
- geotechnical monitoring
- health and industrial safety
- urban impact of the works, interferences.



**A9-CREL MOTORWAY
(LISBON OUTER RING
MOTORWAY).****LOURES-BUCELAS
SECTION.
STRETCHES I AND II
(km 0+000 to km 10+000).
RETAINING STRUCTURES.**

CLIENT: BRISA – Auto-
estradas de Portugal, S.A.
(Highway Concessionaire)

**Final Design and Technical
Assistance:
1993/95**

**SUMMARY DESCRIPTION**

In order to stabilize the slopes of the excavations for the roadway and to support the embankment roadway, various retaining structures were designed, duly adjusted to the landscape and provided with drainage works. The technical assistance to the works was also provided.

The designed retaining structures have particularly considered the site topographic and geotechnical restraints as well as their functions (lining, retaining, mixed).

This way, between km 4+871 and km 5+525, at the upper zone of the excavation slope interesting the slope talus, a retaining anchor wall with one or two anchorage levels (400 kN each) and sloping panels at 1/3 (H/V) was designed. Subjacent to this, at the zone interesting the calcic marble-like pile, a reinforced concrete nailed grate with surface slopes also at 1/3 (H/V) was designed.

Between km 5+265 and km 5+360 a gabion retaining wall was designed to support the motorway platform in an area where surface talus slope of great heterogeneity occur, composed either of fine clayey materials resulting from the change of marls or of granular materials, occurring inclusively, some rocky formations. The maximum height of the gabion retaining wall is 9.0 m.

Between km 6+427 and km 6+574 and km 6+820 and km 6+960, anchorage walls were designed to retain the excavations interesting, once more, slope talus. These walls, with a sloped face at 0,5/1 (H/V) have practically along their entire layout, two anchorage levels (600 kN each) at the clayey sandstone formations. Their height is variable and for each cross-section, they are separated into two levels by a small slope.

Finally, between km 6+575 and km 6+650 a gabion retaining wall with a maximum height of 9 m was designed to support the motorway platform and founded on sandstone and argillite.

Besides the structural design of the various structures composing the retaining solution, the global behaviour of the slope at the excavation zones was analysed, in the static and seismic points of view.

During the construction works, some modifications were made to the structure design between km 4+871 and km 5+575, which allowed to fit the proposed solutions to the real geotechnical conditions and to assure a faster execution of the works. This way, a pre-cast grate replaced the reinforced concrete grate and the upper anchored wall was replaced by a lighter solution composed of a less thick wall with active nailing.

