READY MIX CONCRETE EVOLUTION, DURABILITY, SUSTAINABILITY AND APPLIED INNOVATIONS

Mario Collepardi
Enco srl
Ponzano Veneto (TV)

Dario Rosignoli
Tecnochem Italiana SpA
Barzana (BG)

Stefano Maringoni
Tecnochem Italiana SpA
Barzana (BG)

Özet

Avrupa Standardı **EN 206**, yeni yapıların dayanıklılığının **100 yıldan** fazla süreceğinin ön görüsünü yapmıştır. Yeni yapıların sürdürülebilirliği ve onarımları ile ilgili konular, sürekli evrim ve sürekli yenilik alanlarında zor ve fırsatlarla dolu bir ortamı oluşturmaktadır.

Bu makalede dört yenilikçi teknoloji sunulmuş ve kısaca tarif edilmiştir:

- ➔ Kontrollü ısıl değişim ile **3-5 metre kalınlığındaki** beton su basmanlarının çok düşük hidratasyon ısılı betonlarının dızaynları
- ➔ R.C. inşaatında kullanılan 85 MPa dayanımlı SCC betonu. Milan'daki gökdelenlerin **180 m** yüksekliğindeki sütunları.
- ➔ **Antisismik** güçlendirme projelerine uyumlu yapısal dayanım artışı için Yüksek Çatlaklı Enerji Mikro Betonları.
- ➔ SRA Teknolojisi (Rötre Azaltıcı Katkılar) ile **Derzsiz 11.000 m^2** zemin betonu uygulaması.

1. INTRODUCTION

In an area of 230.000 m2 of Porta Nuova in Milan, in the quarters “Garibaldi”, “Ex Varesine” and “Isola”, is a complete re-urbanisation project in course, with 3 mayor projects, and the construction of very high buildings with a top of 220 m.

All buildings in the area have been subjected to the evaluation criteria of environmental sustainability set by LEED® (Leadership in Energy and Environmental Design) International System for environmental certification.

In particular for concrete, performance criteria have resulted in the supply of products with the highest possible amount of recycled content for both post consumer and post industrial production.

Through collaboration with **ENCO ENGINEERING**, **TECNOCHEM ITALIANA** and **HOLCIM** and in tune with the guidelines of the structural designers **MSC ASSOCIATI** were performed Mix Designs and additives, designed and added "ad hoc" for all quality classes of concrete foreseen: C25/30 - C30 / 37 - C35/45 - C45/55 and C70/85.

Determining factor was also the professionalism of the construction company **COLOMBO COSTRUZIONI**.
Particular attention was devoted to classes C30/37 and C70/85.

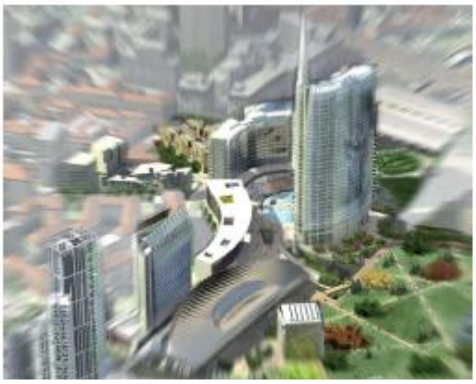


Figure 1 : Milan for Expo 2015
PORTA GARIBALDI

Figure 2 : Milan for Expo 2015
EX VARESINE

Figure 3 : Milan for Expo 2015 “ISOLA“

2. C30/37 SELF COMPACTING CONCRETE VERY LOW HEAT OF HYDRATION FOR THE FOUNDATIONS WITH VERY HIGH THICKNESS FROM 2,2 M TO 5,25 M

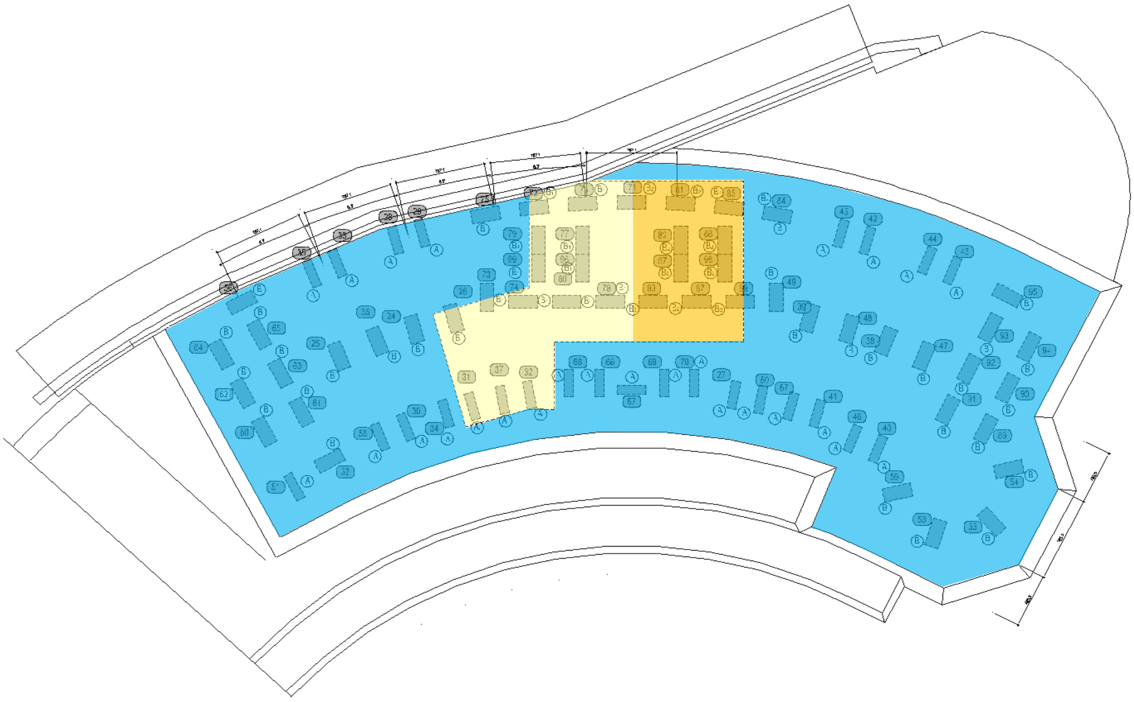


Figure 4 :

Foundation slab thickness **2,2 m**

Foundation slab thickness **4,15 m**

Foundation slab thickness **5,25 m**

A particular concrete type C30/37 of Holcim has been used,containing cement 32,5 R IV A (P-V), formulated “ad hoc” with selected aggregates with maximum Φ 22,4 mm (aggregate/cement ratio = 6,75). Different additives have been used, selected according the necessity of the situation :

a polycarboxylated based super-plasticizer, formulated “ad hoc”, a retarder for the setting and development of the hydration heat, a very fine mineral product with very high pozzolanic activity and an innovative viscosity stabilising admixture.

Thus was obtained, both in the prequalification of the project and on site, a self-compacting concrete with S5/SCC characteristics (flow ≥550 mm) with a very low heat of hydration and meeting the physical-mechanical requirements of the planning stage.

Figures 5-6 : Campione di prova 4 x 4 x 2,2 m

Before starting with the pouring of the decks must be checked by testing on full-scale model, if the mix designs respond to the theorized formulas from the laboratory tests performed on small scale. In particular, a test sample was made, with dimensions of 4x4m 2,2 m high, reinforced with 6 crossed layers steel bars at intrados and extrados with Φ26 mm, which simulates a typical section of the deck of the towers. The project objective was to control, in all weather conditions, the thermal-Δ between inside and outside of the concrete casts within a range of $\Delta t \leq 25$ °C.

To simulate the real adiabatic conditions of the pours, thermal insulation panels were inserted, with a thickness of 10 cm on the caissons of the test sample. Monitoring in time, the development of heat due to the maturation of the concrete was carried out using appropriate instrumentation. Specifically have been included within the project tests with a series of thermocouples NiCr/Ni at different heights in the concrete pours, and with N° 2 LOGGERS-TESTO/T4, frequency reading every 15 minutes in order to be able to record the temperature gradients in' period of time. After about a month after the casting of the sample test, physical testing has been undertaken to check the degree of compaction of the concrete below the lower steel reinforcement.

The results from this trial were very important to refine the optimal mix designs to be used for the towers ground decks. In particular, it was concluded to split up the total thickness of the deck, into 2 castings in order to avoid too high temperature gradients which could cause cracks at the extrados and affect the static efficiency and durability of the reinforcement bars.

2.1. Concrete Mix Design For Massive Casting

Table 1

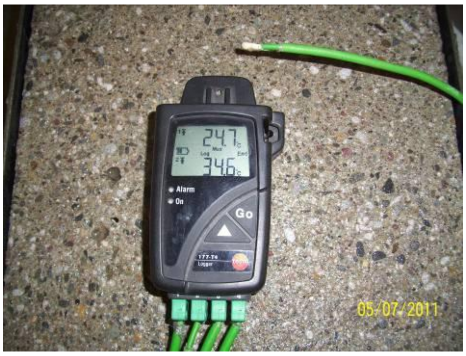
Cement	CEM IV A 32,5 R	300 kg/m^3
Quantity of aggregates (max diameter 12 mm)		1.900 kg/m^3
Rheodinamic active silica	Microbeton® POZ/H	40 kg/m^3
Polycarboxylated superplasticizer retarded	Tecnos® *azur* CB/AB1	5 kg/m^3
Viscosity modifier agent	SCC VISCO	3 kg/m^3
Active water (not absorbed)		144 kg/m^3
	TOTAL WEIGHT	2.392 kg/m^3
w/c ratio	0,48	
w/binder ratio	0,42	

Compressive strength

1 day	n.d.
3 days	25 MPa
7 days	30 MPa
28 days	38 MPa
60 days	46 MPa

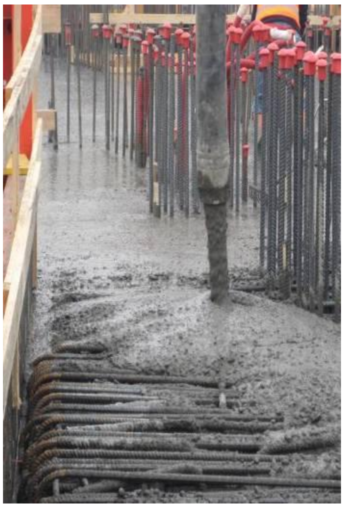
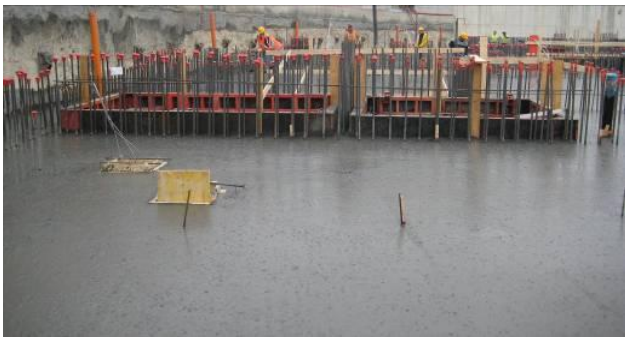
Slump/flow

0 min.	26/65 cm
30 min.	25/64 cm
60 min.	25/64 cm
90 min.	24/62 cm



Figures 7-8 : Data Loggers


Figure 9 : Steel reinforcement

Figures 10-11 : Self Compacting Concrete C30/37 casting

The thermal gradients, systematically controlled with the same equipment and thermocouples NiCr/Ni, were tailored to the specific project (Δt max : 23,3°C).

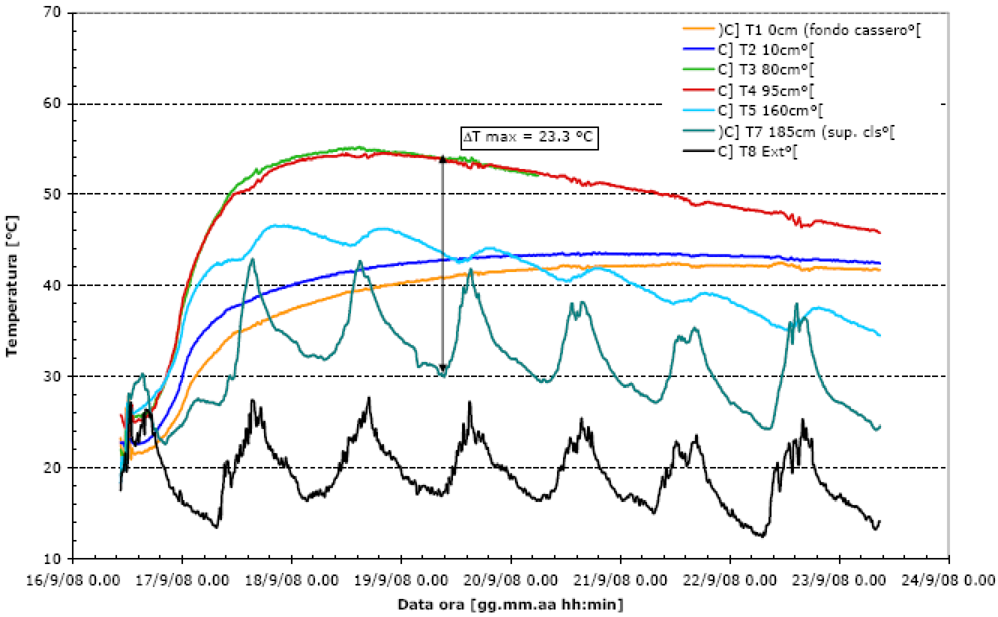


Figure 12

3. C70/85 FOR THE LOAD BEARING COLUMNS OF THE STRUCTURE

C70/85 (reaching 95 MPa) Self Compacting Concrete (flow > 600 mm),∅ max aggregates 12 mm, w/c ratio ≤ 0,35 , maintaining the pumpable fluidity properties for 120' , pumpable up to 150 m high , control and containment of the thermal gradients and stresses, resistance to fire R 120.

3.1. High strength concrete mix design for structural columns

Table 2

Cement	CEM I 52,5 R	552 kg/m^3
Quantity of aggregates (max diameter 12 mm)		1.727 kg/m^3
Rheodinamic active silica	Microbeton® POZ/H	67 kg/m^3
Polycarboxylated superplasticizer, retarded, shrinkage reducing	Tecnos® *azur* CB/AB1/MOD	11,49 kg/m^3
Fibers	FIB-energy® MC 40/8	0,88 kg/m^3
Active water (not absorbed)		180 kg/m^3
	TOTAL WEIGHT	2.460 kg/m^3
w/c ratio	0,33	
w/binder ratio	0,29	

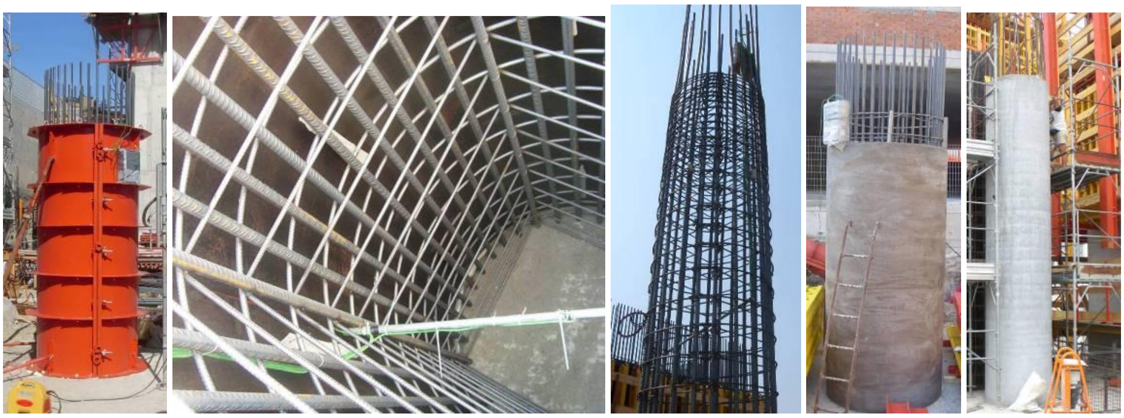
Compressive strength

1 day	53 MPa
3 days	66,1 MPa
7 days	73,2 MPa
28 days	95,6 MPa

Slump/flow

0 min.	28/60 cm
30 min.	27/61 cm
60 min.	27/60 cm
90 min.	28/59 cm

The experimental phase of controlled thermal stress was performed with thermocouples NiCr/Ni at different heights of concrete pouring and with N° 2 LOGGERS-TESTO/T4 with frequency of reading every 15 minutes, which allowed to record the temperature gradients over the time.



Figures 13, 14, 15, 16, 17 : Formwork and steel reinforcement before and after castings.

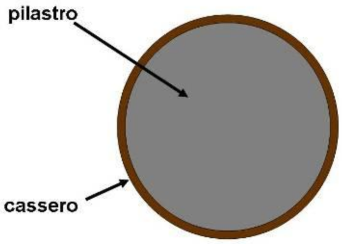


Figure 18 : Due to the different thermal insulation of concrete in the center(nucleus) and in the periphery, a temperature gradient between the hot test and coldest parts of the structure is created.

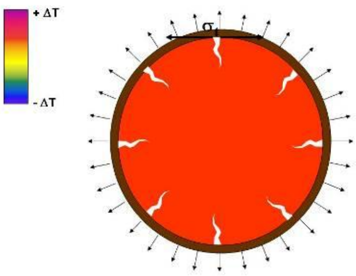


Figure 19 : Cracks may appear on the surface during the first 2/3 days due to compressive stresses of the warmer core which shall expand causing tensile stresses with the cooler periphery on the surface cooler.

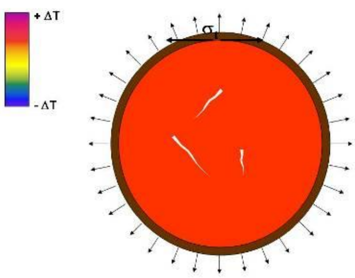


Figure 20 : The cracking can also occur in the core of the structure during the cooling phase for the onset of tensile stresses in the core, which cools more slowly than the periphery. The elastic modulus in this phase is increased, so the dimensional changes cause higher tension.

The protection of the casted concrete is specified by INSULATOR-tec 10 in the phase when the thermal gradients > 25°C/m.

Figure 21

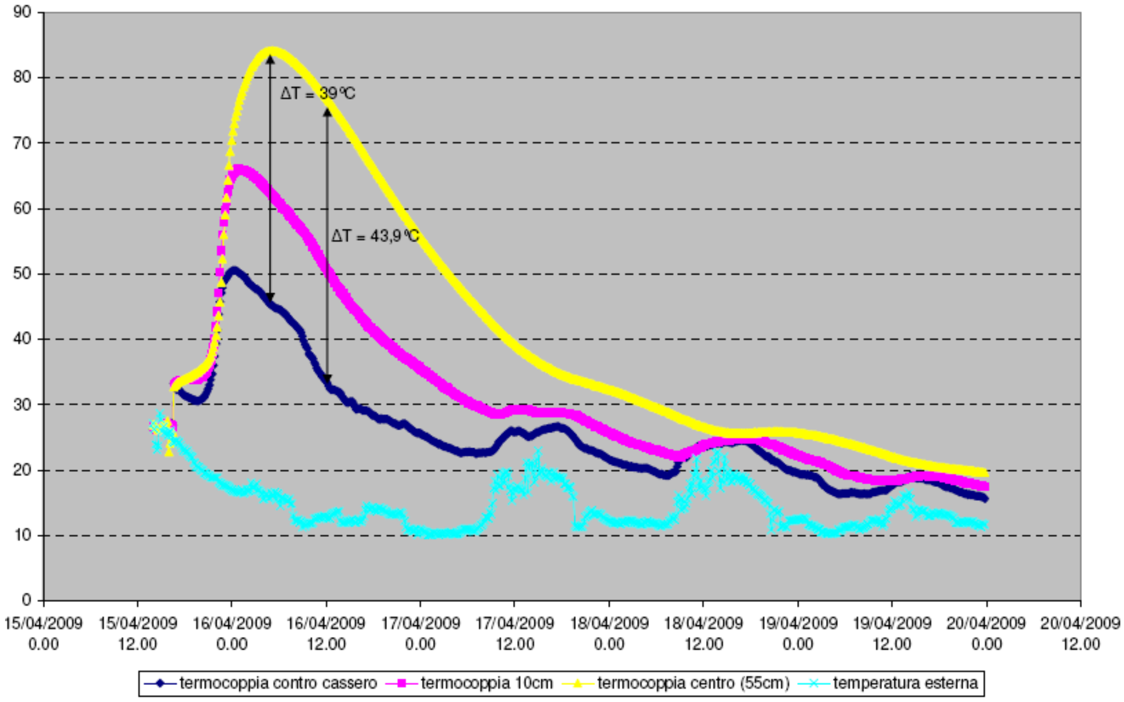


Figure 22:Measurement of the thermal gradients in beam with diameter 1,10 m - h =6 m - Rck 85

Figure 23: Ready mix plant on the jobsite

Figure 24:Concrete Rck 85 pumped up to 150 m

Figures 25-26 : Views of the construction

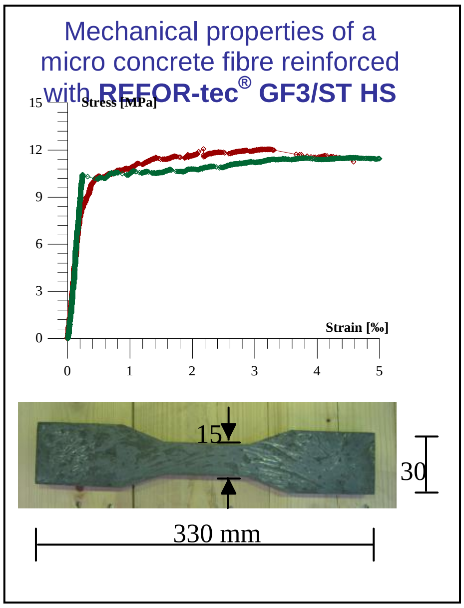
4. REFOR-tec® UHPFRCC
Ultra High Performance Fiber Reinforced Cementitious Composites

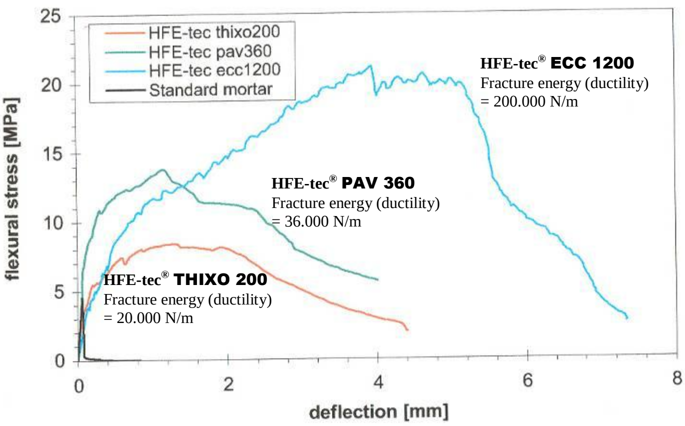
For structural and antiseismic strengthening and retrofitting. The innovation consists in the absolutely excellent physical and mechanical characteristics and performances obtained and in the wide possibility of modulation for diversified project requirements.

Table 3

	Standard concrete	**REFOR-tec® UHPC UHPFRCC**	**HFE-tec® ECC HPECCMFC**
Elasticity modulus [GPa]	30 - 35	35 - 50	10 - 25
Compressive strength [MPa]	30 - 50	65 - 280	25 - 70
Tensile strength at rupture (MPa)	2	6 - 12	3 - 5
Limit of proportionality [MPa]	-	20 - 40	10 - 15
Flexural strength at rupture [MPa]	5	13 - 80	8 - 20
Ductility – Fracture Energy (N/m)	**low 100**	**8.000-25.000**	**12.000- 200.000**
Deformation at rupture (uniaxial direct tensile strength)	**0,01 %**	**0,5%**	**3%**
		50 times	300 times

UHPC - **U**ltra **H**igh **P**erformance **C**oncrete ; **UHPFRCC** - **U**ltra **H**igh **P**erformance **F**iber **R**einforced **C**ementitious **C**omposites ; **ECC** - **E**ngineered **C**ementitious **C**omposites ; **HPECCMFC** - **H**igh **P**erformance **E**ngineered **C**ementitious **C**omposites **M**ultiple **F**ine **C**racks.





Figures 27-28

MORE THAN 100 SUCCESSFUL APPLICATIONS MADE !

Structural strengthening of columns, floors, beams, nodes, shear walls - Concrete & masonry antiseismic strengthening and retrofitting - Repairs after fire - Ductile slabs in substitution of traditional highway joints.

5. NO JOINT 11.000 M^2 CONCRETE PAVEMENT CONSTRUCTION WITH SRA – SHRINKAGE REDUCING AGENT – TECHNOLOGY

The concrete casting was organised in stages of 500 m^2 each, without any joints. In order to provide structural continuity between the stages of the project transpassing connecting reinforcement has been used, and for the containment formwork, ribbed steel net. This steel net provides better structural continuity with respect to a traditional steel formwork, as it ensures a roughness on the surface allowing of a better adhesion of the next casting. With regard to action to control the hygrometric shrinkage, the progress of the different concrete castings was carried out "on chessboard pattern" so that the casts of the second phase could be carried out, already within the square, surrounded by previous casts, in order to have a more effective contrast expansion with an improvement of the initial coaction, opposed to the formation of cracks and the opening of construction joints.

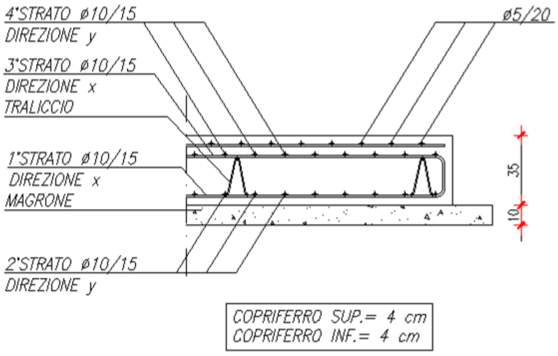


Figure 29: Steel reinforcement ; Figure 30 : Helicoptering after laser-screed levelling


Figure 31:Parking area in activity

Table 4

Compressive strengths class:**C 25/30** (obtained>**40)** - Restrained expansion after 60 days ≥250 μ/m - Consistency class: **S5 -** Exposition class: **XC1**	
Components of the concrete	**Kg/m^3**
Cement Holcim 32,5R II/B-M – Holcim Merone	360
*Tecnos® **azur CB/ER** polycarboxylate super plasticizer, with very high efficiency and providing long workability*	3,96
***SHRINKO-tec® nano 4** nanotechnology additive for the physical-chemical reduction of the hygrometric shrinkage*	4,7
***CEMEX M 1000/1** shrinkage compensation admixture*	40
AGGREGATE:0÷12 mm	200
AGGREGATE: 0÷10 mm	979
AGGREGATE: 10÷25 mm	690
Active water (W/C 0,43)	156
Total Kg/m^3 without inclusion of air	**~2.434**