3.1 Reconstruction between temporary and definitive: the CASE project

G.M. Calvi[1] and V. Spaziante[2]

3.1.1 The idea

What is the time difference that distinguishes a temporary or provisionally home from a permanent or final? It is not easy to respond to this question, if you consider the seemingly enduring eternity of what in Italy is built with the objective to last for months, or for a maximum of few years.
On the other hand, in Italy it is possible to refer to the technical code of 2008 (NTC 2008), in which the nominal lifetime of a structure is defined as *the number of years in which the structure can be used for the purpose it was built for*, it is indicated in a table and it needs to be specified in the design documents.
It is interesting to note that the code only indicates a maximum for provisional works (10 years) and two minima for ordinary and important works (50 and 100 years respectively). If one sticks to this data, it should be concluded that all the provisional works that were constructed in the aftermath of the earthquakes that took place after WWII should actually be considered permanent, since they had a lifetime longer than 10 years (ignoring the fact that apparently between 10 and 50 years works can neither be called provisional, nor permanent).
If then the provisional does not exist from a durational point of view, it would be useful to wonder whether it makes sense that it would exist looking at energy consumption, sustainable environment or pollution. It would also be useful to wonder whether buildings could be constructed with environmental characteristics and safety level similar to that required for permanent ones on a temporary basis and with cost per unit similar to provisional ones. If this should be the case, it would be logical to propose to build provisional houses with characteristics of the permanent ones.
A first complete conceptual proposal, with 3D-rendering and preliminary calculations was submitted on April 16th, together with several comments. It was hypothesized to deliver the buildings for 3,000 inhabitants within 5 months, guaranteeing seismic safety by means of an isolation system at the level of an urban block, and proposing elevate standards of living, technology and environment protection. The pursuit of these objectives, apparently impossible, was based on the construction of large isolated plates and the subsequent assembling of pre-fabricated three-storey living units. The need for the project to be as much as possible independent from local soil conditions and from the unknown construction technology (many different ones would have been necessary to meet the deadlines) became immediately clear. To this end it was stated the need of urgently identifying the possible building technologies compatible with the timing programme and the technical constraints, of selecting technical and commercial partners and of exploring the production capacity of the market.
The time programme was defining in four weeks the date to open the construction sites, i.e. to start construction by mid-May, to deliver houses to 3,000 inhabitants by September.
The economic analyses indicated an estimated cost of 120 million euro, VAT excluded, for 3,000 inhabitants, with a 20% uncertainty rate and without considering furniture, purchase of the terrain and photovoltaic installations.
In preliminary calculations it was assumed to use friction pendulum devices [2-8], with a radius of curvature of 4m, a vibration period of 4s, a displacement capacity of about 300 mm, a friction coefficient between 3 and 5% and an equivalent viscous damping between 20 and 25%. The alternative of using rubber isolators was also taken into consideration, but appeared in this specific case to be less competitive, considering the relatively low axial forces and the large horizontal displacement demands.
In the days immediately following, several aspects that would have permanently defined the project were discussed and clarified:

- The reduction of each one of the isolated plates to about 20 by 60 m, suitable to sustain three-storey buildings with each floor surface of about 600 m^2, with a capacity of about 80 inhabitants in 25 to 30 apartments. Plates of this dimension should allow an adequate flexibility in relation to the

[1] Fondazione Eucentre - Centro Europeo di Formazione e Ricerca in Ingegneria Sismica, Pavia. www.eucentre.it
[2] Dipartimento della Protezione Civile, Roma. www.protezionecivile.it

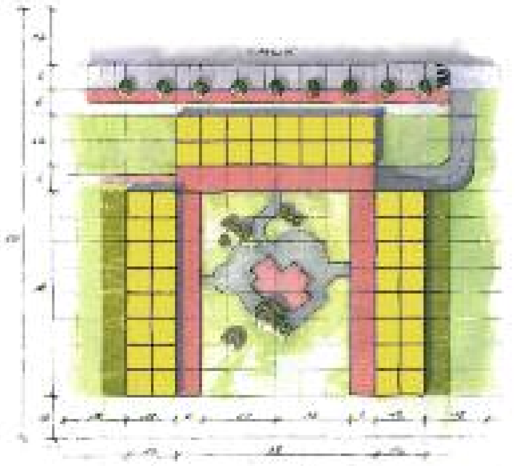


Fig. 1
One of the first sketches of the project illustrating the logic of the buildings constructed on isolated plates.

Fig. 2
A plan sketch made by architects Ragazzi e Hoffer as to illustrate the logic of the infrastructure in a court open to pedestrians.

Fig. 3
One of the many 3D renderings used to illustrate design hypotheses.

plane altitude conditions of the areas to use (at that moment unknown) and the construction technologies, also unknown;

- The definition of 150 as the approximate number of plates to construct and therefore of about 12,000 inhabitants to settle in;
- The division of the intervention in numerous small villages, consisting of 4 to 20 plates and hence a number of inhabitants between 300 and 1,600;
- The definition of a serial timesheet in which a group of 30 plates should be finished about 15 days after the previous group, which implied a forecast of delivery of the apartments in 5 tranches for 2,400 inhabitants a time, with deadlines spread out between 30 September and 30 November;
- The decision to manage the entire project directly, without intervention of a general contractor, setting up a non-profit technical structure that responds directly to the Civil Protection Department (DPC). It was thought that this way it would be possible to save substantial economical resources, mainly on general additional costs and to have a more accurate control on deadlines and quality of the project.

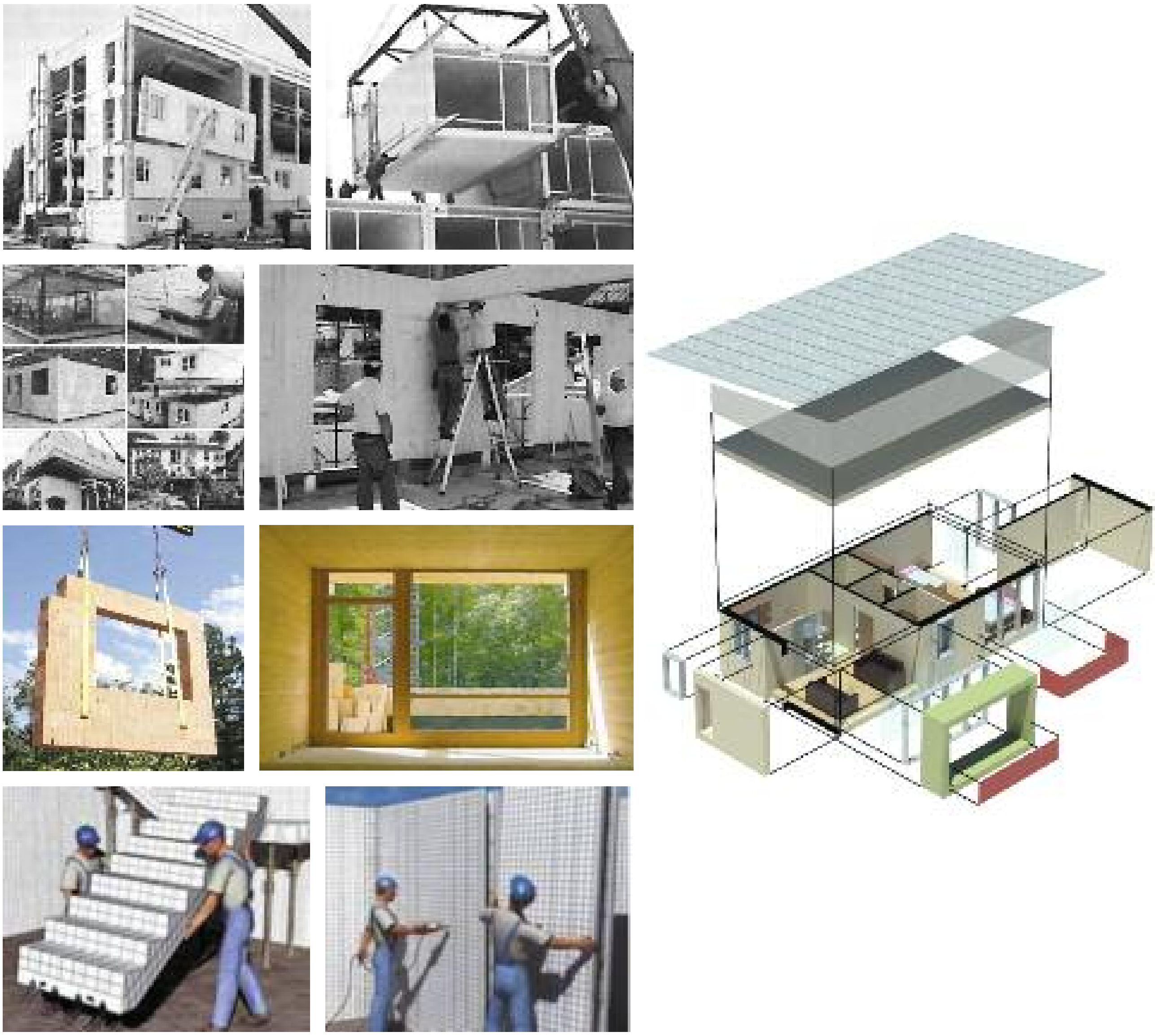


Fig. 4
Images used in the preliminary phase to illustrate possible technologies for the assemblage of the buildings.

3.1.2 The organisation

The definition of an operational, management and outsourcing structure, of personnel roles, activities and their interaction, time programme and milestones required several days of intensive work and was completed and formalised by May 8th. The way the project is managed is very innovative with respect to the schemes that are normally adopted, and not only in Italy. In fact a single-purpose consortium was created (named *ForCASE*), formed by Eucentre (a non-profit foundation, centre of competence for seismic risk of the department of civil protection, founded by four public institutions and with a nature of 'public company' in Europe) and two construction companies, (*ICOP* and *Damiani*). The two companies agreed to operate in this context as non-profit entities and not to participate in any other reconstruction activity in Abruzzo. Their role would have been that of a technical office, and therefore to facilitate the consortium to act on behalf of the CPD as a *general contractor*, with the capacity to manage directly supplies purchasing, to coordinate activities on the construction site, to arrange and verify all accounting matters.

Obviously, the consortium had as well the main task of carrying out all designing and construction management activities, under the responsibility and coordination of the authors of this article. Coherently with what has been briefly described, the operational organogram demonstrates five main areas of actions: two being related to design activities, two to management and accountancy activities and one to project coordination.

In order to obtain maximum efficiency, in terms of time and costs, and to ensure quality control, three different operational modalities for contracting and execution of the work were identified:

- For the activities of preparation of the construction site and infrastructure works, it was decided to mainly use local contraction companies;
- For the foundation and isolation systems, it was opted to act directly as a general contractor acquiring materials and supplies, such as concrete, welded wire meshes, steel columns, isolation devices, formwork positioning, concrete casting, etc.;
- For the construction of the housing structures it was decided to launch a call for bids that included final design and global construction, allowing the use any building technologies compatible with the needs and available time, and selecting the proposals with the highest quality and the lowest cost.

The economic quantification of the costs for the management of all activities was estimated based on the pure cost of the staff assigned to this temporary job (in months), on a monthly cost, in general between 3,000 and 12,000 euro (these are costs for the consortium, not net salaries), and on a sum to cover cost of accommodation and travel, that could in any case never exceed 3,000 euro per person per month. As all the activities would be executed within the non-profit framework that characterizes the Eucentre Foundation and the ForCASE consortium, the estimations were considered as a maximum not to be exceeded, while the real costs would be subjected to accountability checks.

The DPC would directly execute, in cooperation with the consortium, all the activities related to:

- Definition of civil protection ordinances, possibly needed for the completion of the project;
- Finalisation and publication of call for bids;
- Stipulation of contracts;
- External checking and control;
- Relations with institutions and obtainment of permissions;
- Identification of the intervention construction sites, expropriations of lands and related activities.

The Department of Civil Protection would directly execute, in cooperation with the consortium, all the activities related to:

- Definition of Civil protection ordinances, possibly needed for the completion of the project;
- Finalisation and publication of call for bids;
- Stipulation of contracts;
- External checking and control;
- Relations with institutions and obtainment of permissions;
- Identification of the intervention construction sites, expropriations of lands and related activities.

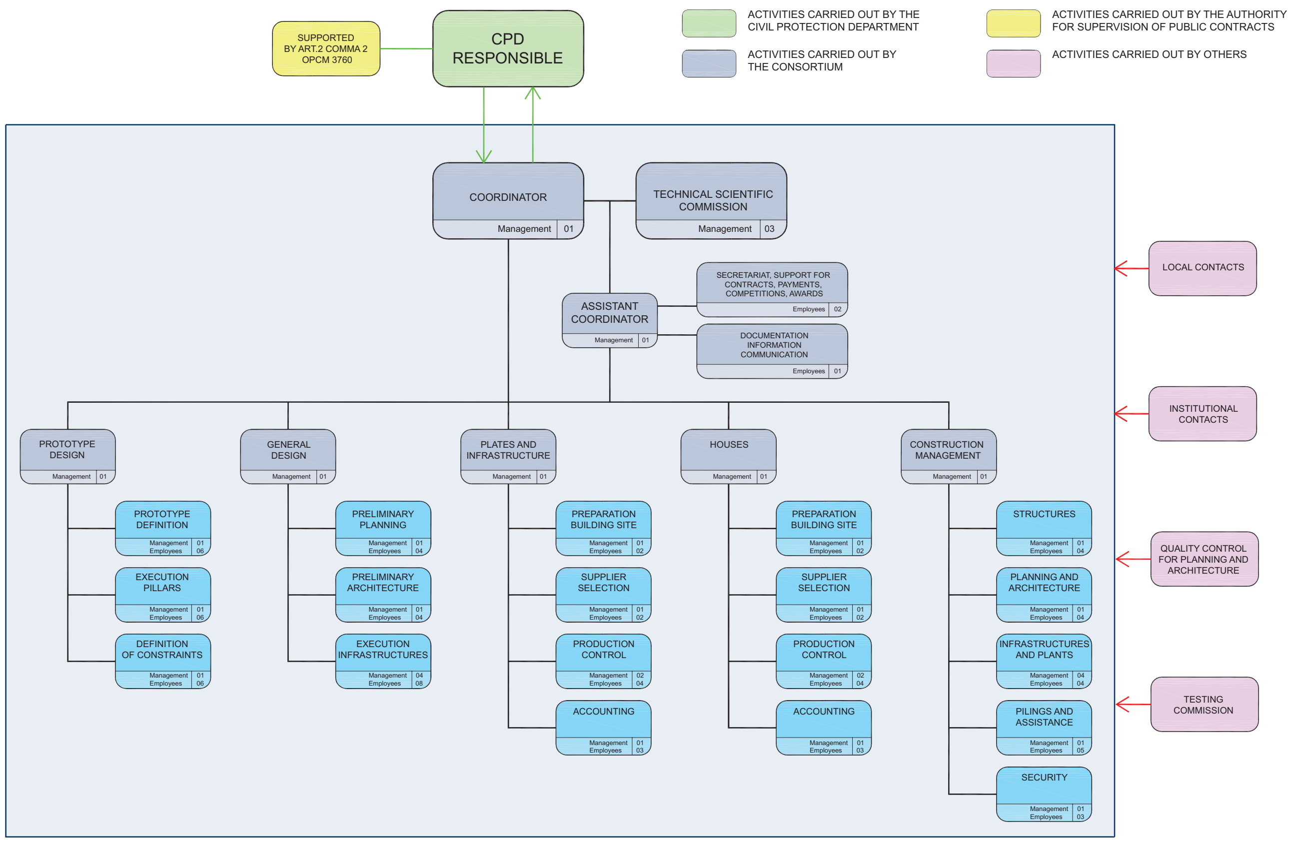


Fig. 5
The personnel and work organization plan set up in the preliminary phase.

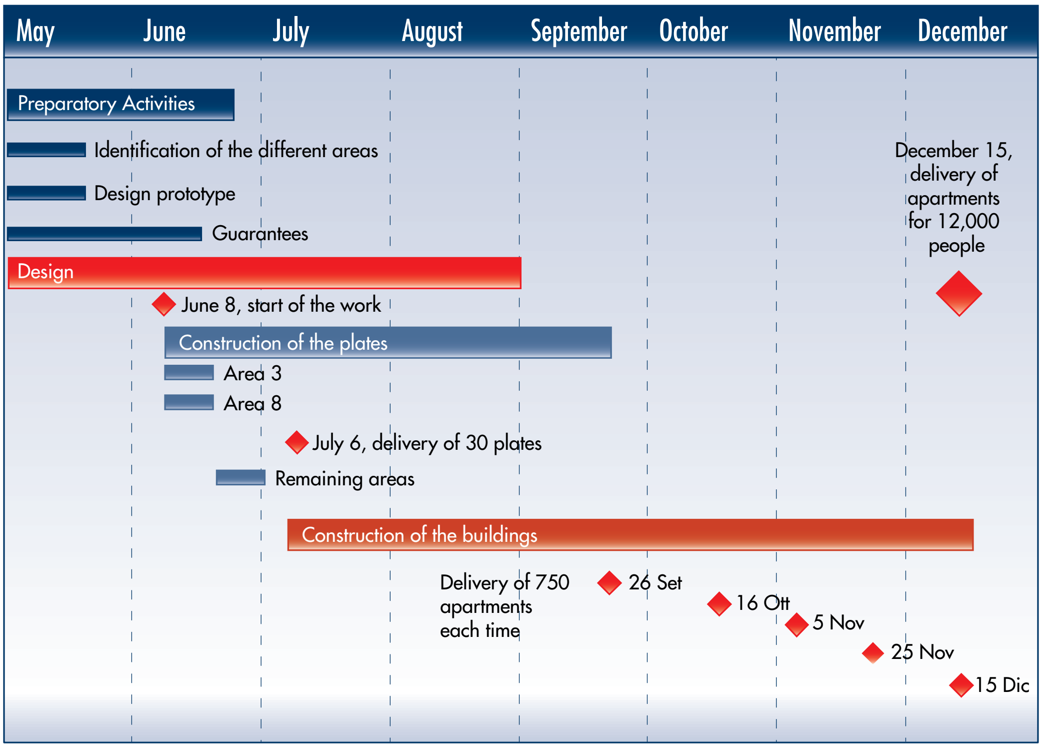


Fig. 6
A simplified version of the extremely detailed and complex time schedule that allowed daily overviews on each aspect of the project and the construction.

3.1.3 Infrastructures and architectural design

The architectural project of a building unit, as briefly presented, favoured the development of different types of apartments, as a function of family compositions, which resulted in 109 different shapes after the selection of 16 contracting bids, as discussed later.

Regarding the choices on infrastructure, it needs to be highlighted that a first guiding concept was that of placing the settlements in the neighbourhood of existing villages that had suffered severe damages because of the earthquake, to be able to relocate the people within their own territory, to preserve the close ties that people have with land and neighbours.

This general principle was confronted with technical difficulties deriving from non-ideal geomorphic, hydrological and geotechnical circumstances of the areas, to finalise the best possible selection of the areas of intervention.

Once the settlements had been defined and sized as a function of quantitative needs and land capacity, considering the dimensional and morphological characteristics of the location, the problem of existing infrastructures (roads, pipelines, sewing system, etc.) and of their improvement and integration had to be faced.

Finally, the population indices could be defined, starting from figures between 100 and 150 inhabitants per hectare, for location in more rural or more densely populated areas. Such figures imply a rather sparse settlement typology, marked by large green areas.

A final infrastructure index had been identified by assigning 30% of the land surface to services and facilities, such as leisure, sport, shopping centres or education and religious structure.

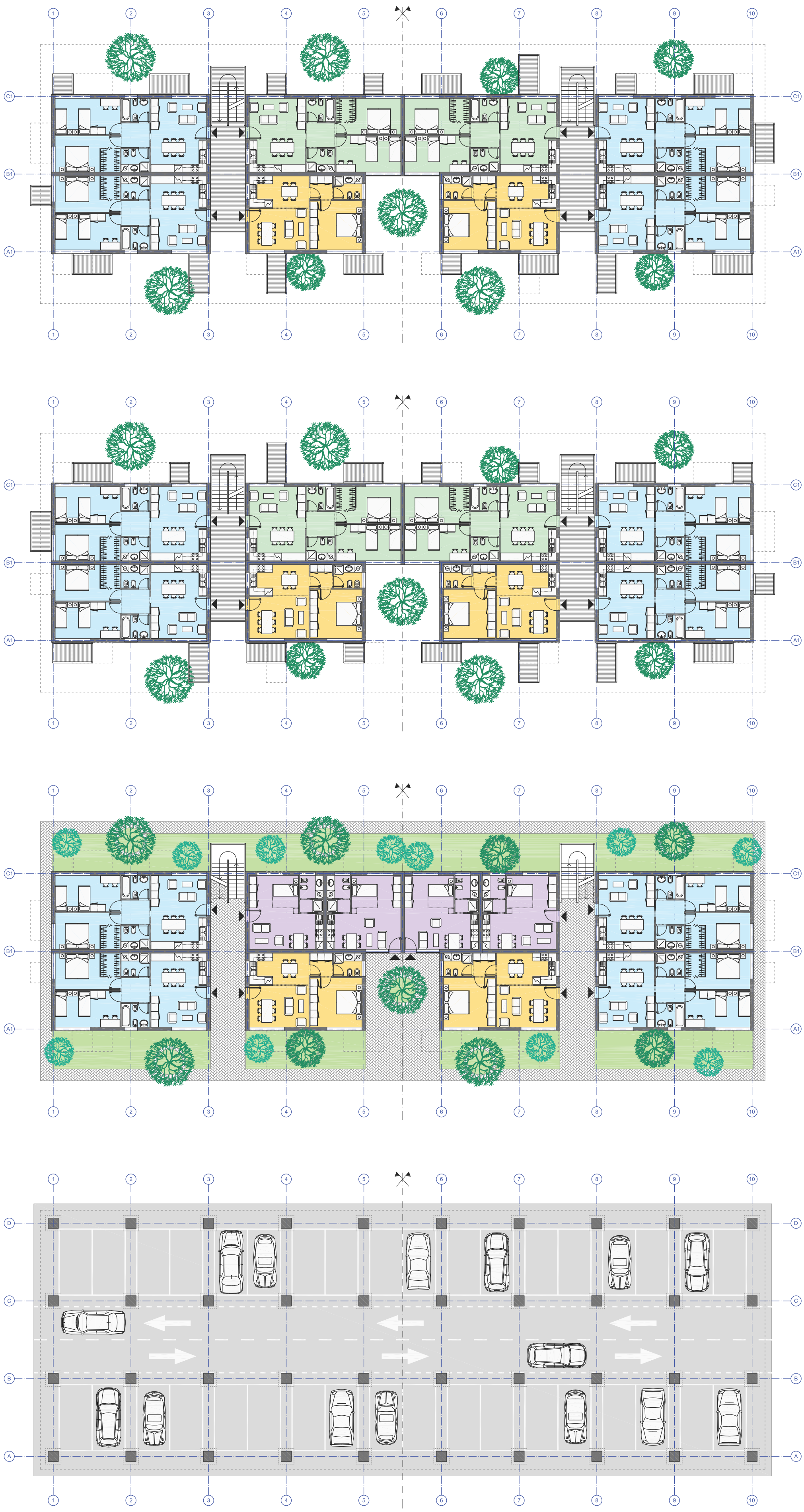
Based on these premises the final urban design of the areas was completed, obviously combining the building units previously described (essentially consisting of three inhabited floors above a covered parking), also considering exposure to sunlight, valley and mountain views, steepness of terrain.

Driveways and walking paths were kept separated to the maximum possible extent, generally locating vehicles roads on the outer skirts of each area, with access limited to parking lots and ground floors of the buildings, also used as parking. The walking paths were designed eliminating all architectural barriers, connecting green areas and inhabited levels to road systems and parking lots with external elevators when needed.

The final character of the new settlements tried to combine in a optimal way people needs, environmental and landscape requirements, use of existing infrastructures and construction of new ones, in an integrated vision.

Later, another problem had to be faced, i.e. how to combine each one of the specific building units (at this stage 150, in 20 different locations) to each one of the 16 different typologies pro-

Fig. 7
An example of the plans that were designed for the bids of housing construction, with an underground parking between the two plates.



SECOND FLOOR
height +6.50 m

28 sleeping accomodations

FIRST FLOOR
height +3.40 m

28 sleeping accomodations

GROUND FLOOR
height +0.30 m

24+4 sleeping accomodations

TOTAL 80+4 sleeping accomodations
SLP total: 556 mq x 3
SLP total:1698 mq

DOWNSTAIRS FLOOR
height -3.00 m

36 boxes

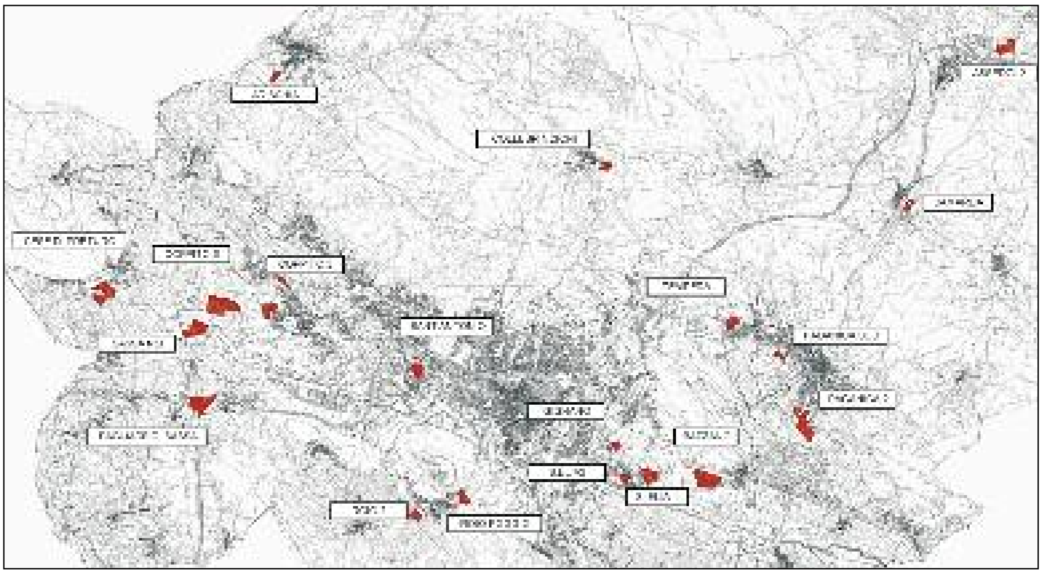


Fig. 8
Location of the construction sites, all within the municipality of L'Aquila.

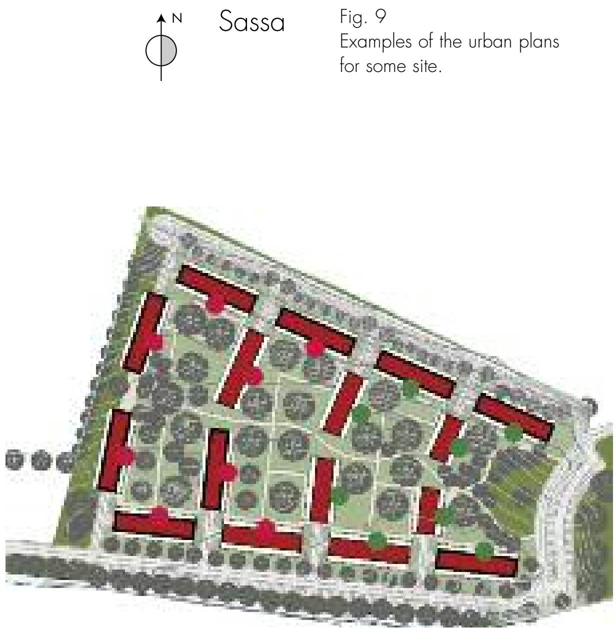
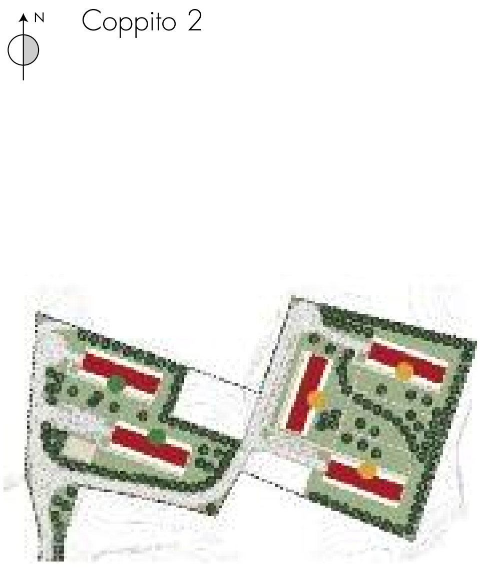


Fig. 9
Examples of the urban plans for some site.



posed by the companies who won the call for bids. Choices had to be made in relation to construction technology and material, external aspect, number of buildings awarded to each company, construction plan and schedule proposed by each company.

Finally, considering the high environmental value of the landscape, the design and realisation of the green areas was again the subject of a public, international call for bids, where again cost, time and quality of the proposal were considered to select the winning bids.

3.1.4 Structural Design

Preliminary considerations

The structural design of the buildings constitutes the fundamental element that allowed the development of the entire project and is extremely simple in its basic logic: two reinforced concrete plates, separated by columns and isolators, the lower one being in contact with soil and the upper one with the building. The plates were designed without knowing the local soil properties, nor the weight and plan distribution and structure of the buildings. Therefore for both aspects conservative assumptions were used, to be verified later. In a few cases, some potentially selected construction location had to be discarded because the soil properties appeared to be unsuitable.

It should be noted that the two plates are characterized by similar flexural actions induced by gravity, if it is assumed a uniform distribution of the building load and of the soil reaction. Preliminary evaluations, based on a column span of 6 m in both directions (convenient for parking arrangements), lead to a required thickness of both plates of 500 mm.

The weight of each building, with three floors of about 600 m^2 each, was estimated in a maximum of 21 MN, with a consequent total maximum weight of slab, dead loads and building details of between 30 and 40 MN (or an average weight per column of about 1 MN).

The first vibration period of the building can be estimated between $\mathbf{T_s}$ = 0.25 and $\mathbf{T_s}$ = 0.45 s, using the equation:

$$T_S \cong C_S H^{0.75}$$

in which **H** is the height of the building and $\mathbf{C_s}$ is 0.05 for wall structures, 0.075 for reinforced concrete frames, 0.085 for steel frames. It is however well known that equations of this sort tend to underestimate the real vibration period resulted from a secant stiffness to yield, that for the examined buildings could arrive at values between 0.8 and 0.9 s, [9, 10].

Based on these considerations, the design period of vibration of the isolation system was selected in the range of 4 s.

It was also preliminary observed that even an extreme temperature variation of ±30 °C, leads to variations in length of about 8.5 mm on each side of the axe of symmetry, that would not induce excessive horizontal loads into the columns.

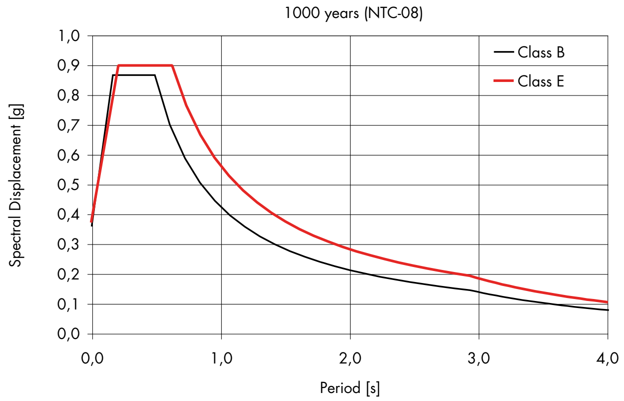
Seismic action

Seismic action and in particular spectral demands in acceleration and displacement are discussed in detail elsewhere in this volume [11]. Here it is however important to note that the fundamental parameter to be assessed for a proper design of the isolation system is the maximum displacement demand at a period of about 4 s. The spectra derived from the registrations of April 6th show generally displacement demand of less than 120 mm, with one exception, the AQK registration, in which spectra values are close to 250 mm. The code spectra for events with return periods of 1000 years, to be used for the design of the isolation system, have values of about 300 mm for soil type B and 400 mm for soil type E. These values can be significantly reduced in presence of energy dissipation, as a function of an appropriate equivalent damping, according to the η factor:

$$\eta = \sqrt{\frac{10}{5+\xi}}$$

where ξ is the equivalent viscous damping value, that could be in the order of 10-15% for rubber bearings and of 20% for friction sliders. The values obtained from the reduction coefficients are between 0.6 and 0.7, with consequent estimations of displacement demands of about 250 mm for soil type E.

For the non-linear analyses the code spectrum for vertical actions has also been considered, while for the building phases it was defined as a 'construction event' consistent with what indicated in addendum A of Eurocode 8, part 2 [13]. Such an event appeared to be consistent with registrations corresponding to a magnitude of 4.0, and was thus considered reasonable. While the demand in terms of acceleration was significant (in the order of $\mathbf{a_g}$ = 0.10 on stiff



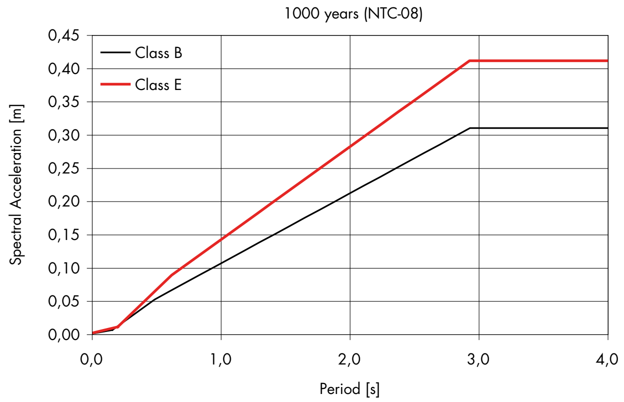


Fig. 10
Acceleration and displacement spectra of an event with a 1000 year return-period in L'Aquila, according to the Italian code [1], soil category B and E, damping 5%.

soil), the displacement demand was negligible.
Eight sets of spectrum compatible accelerograms have been used for non-linear analyses, derived from registrations made in L'Aquila (3 records), and during the events of Imperial Valley in 1979, Loma Prieta in 1989, Northridge in 1994, Kobe in 1995 and Taiwan in 1999 (one for each of these events).

Isolation system
The design and the verification of the isolation system was carried out considering the possibility of adopting two different configurations, characterised by different devices, one based on the use of 12 elastomeric isolators, together with 28 multi-directional sliding pot-bearings and the other on the use of 40 isolators sliding on spherical surfaces, universally known as *friction pendulum* [FPS, 2].
Both choices are compatible with the project requirements, in different ways. Actually, the smaller dissipation capacity of the system with elastomeric isolators (estimated to be equivalent to 12% damping) with respect to the one with FPS isolators (estimated damping 20%,) requires a larger displacement capacity; in the order of 300 to 360 mm for the elastomeric isolators, versus 260 mm for the FPS, depending on the soil properties.
Obviously other combinations may be possible,

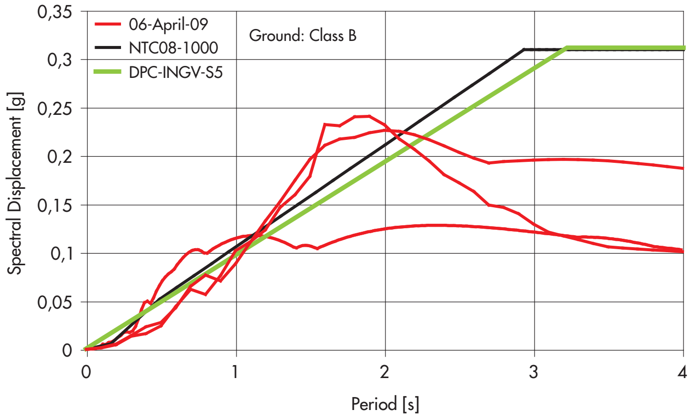


Fig. 11
Comparison of several spectra recorded on April 6th on soil type B, code spectra for an event with a 1000 year return-period according code [1] and results of a recent research project (DPC-INGV-S5 [2]).

also related to the various displacement demands for isolators placed in different positions (because of the eccentricity of the loaded mass, even only accidental, the demand at the perimeter is larger than that closer to the slab central area). It was therefore allowed to bidders to propose different solutions, provided that they were respectful of design performances and input. The result of the call for bids, in which FPS systems were preferred, should not be considered as a general demonstration of superiority with respect to elastomeric devices, but rather as a consequence of the specific conditions of this project, characterised by relatively large horizontal displacement demands, low vertical forces on the devices and relatively low horizontal stiffness (as discussed, vibration periods of the order of 4 seconds were assumed). This was the reason why elastomeric isolators had to be coupled with pot bearings: the use of rubber bearings alone would have resulted in stiffness values incompatible with the requirements of the project.

In the case of the FPS devices, the force corresponding to a displaced position is defined by the following equation:

$$F = Mg\mu + \left(\frac{Mg}{R}\right)d$$

In which **Mg** is the axial action (**M** is the mass and **g** the acceleration of gravity), **R** = 4 m the radius of the spherical surface, **μ** = 3% is the friction coefficient and **d** the displacement of the isolator. The least favourable conditions for the verification of displacement capacity of the isolation system versus the corresponding demand are likely to be those of a rigid and heavy superstructure, i.e. those of a large participating mass and deformations concentrated in the isolation system. With a configuration of this sort, the system global characteristics (40 pieces) resulted to be ass follows.

Effective stiffness, secant to the design displacement:

K_{eff} = 14,615 kN/m

Corresponding period of vibration of the isolation system (note that in general heavier structures are also stiffer, therefore characterised by lower vibration periods):

$$T = 2\pi\sqrt{\frac{M}{K_{eff}}} = 3.29s$$

Corresponding equivalent damping:

$$\xi_{FPS} = \frac{2 \cdot \mu \cdot M \cdot g}{\pi \cdot K_{eff} \cdot d} = 0.201 = 20.1\%$$

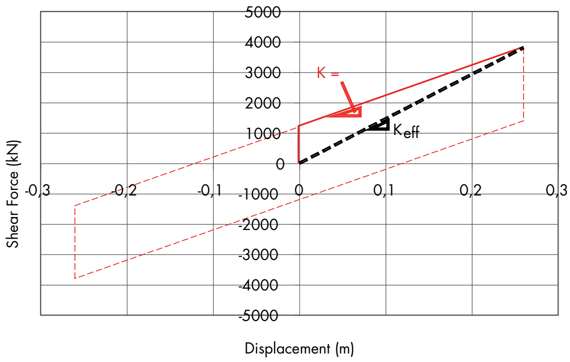


Fig. 12
Force – displacement response of a system of 40 isolators and heavy superstructure.

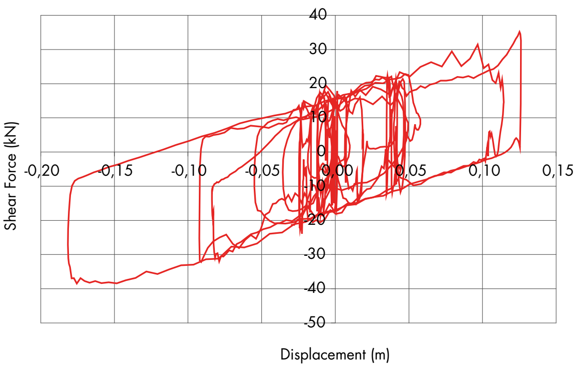


Fig. 13
Force – displacement response of the system considering axial force variation due to vertical acceleration and global interaction response [2, 4].

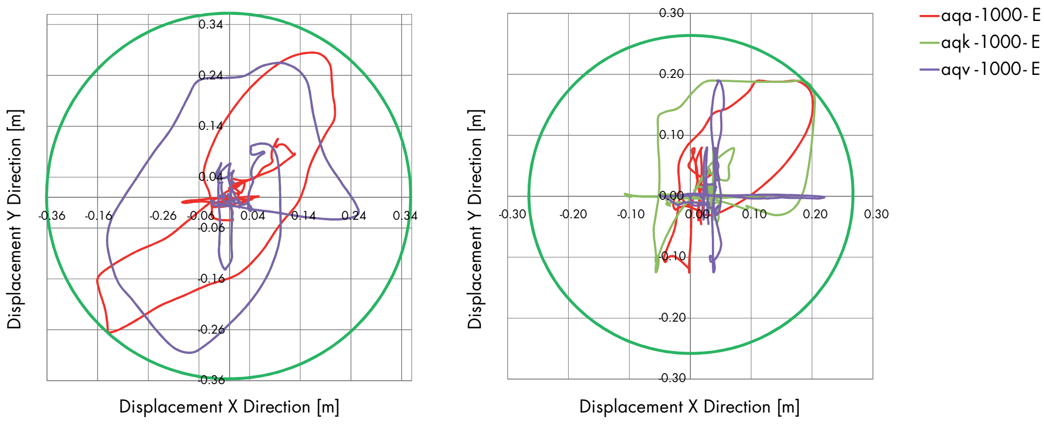


Fig. 14
Examples of displacement histories for an elastrometic isolator (left) and for a FPS isolator (right), subjected to events with a 1000 year return period derived from 3 registrations in L'Aquila, compared with capacity circles of 360 mm (left) and 260 mm (right).

Verification of slabs and columns

The foundation and isolation plates have been subjected to numerous finite element analyses, that allowed to calculate the maximum bending and shear demand levels for several load combinations, to design the reinforcement, generally made by welded wire meshes to favour a fast positioning, and to verify the resulting action combinations with appropriate strength domains. Local verifications for loads concentration at the column ends were also performed on both slabs, considering the consequences of the substitution of a bearing as well. This operation was needed in hundreds of case during construction, when the isolators were not ye available at the time of casting the upper slabs.

The columns have been designed and verified considering either the case of reinforced concrete and of steel, again to allow the use of various technologies and thus reducing the operation time. For the same reason steel columns were in general preferred, even if more expensive, using concrete only when no steel elements were ready to be mounted.

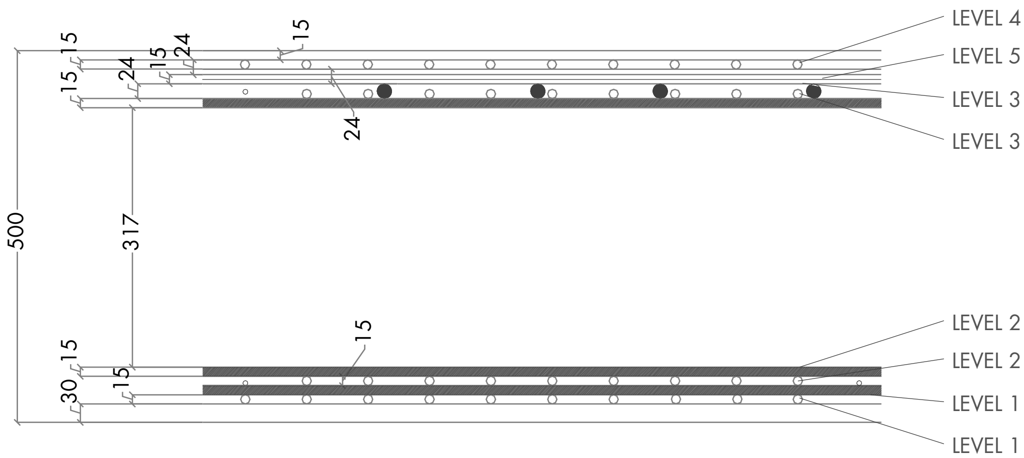


Fig. 16
Examples of reinforcement distribution in a section of the isolated plate.

	Steel reinforcement
Level 1	Welded mesh D = 14 mm, at 100 mm in both directions
Level 2	Welded mesh D = 14 mm, at 100 mm in both directions
Level 3a	Welded mesh D = 14 mm, at 100 mm in both directions
Level 3b	7 rebars D = 24 mm, L = 2,400 mm, at 250 mm (parallel to axis Y), centred on column heads
Level 4	Welded mesh D = 14 mm, at 100 mm in both directions
Level 5	7 rebars D = 24 mm, L = 2,400 mm, at 250 mm (parallel to axis Y), centre on column heads

Fig. 15
Example of bending stresses in the foundation plate, for gravity loads (1st row, moments around the two axes of symmetry in kNm/m) and for seismic loads (2nd row: maximum values, and 3rd row: minimum values).

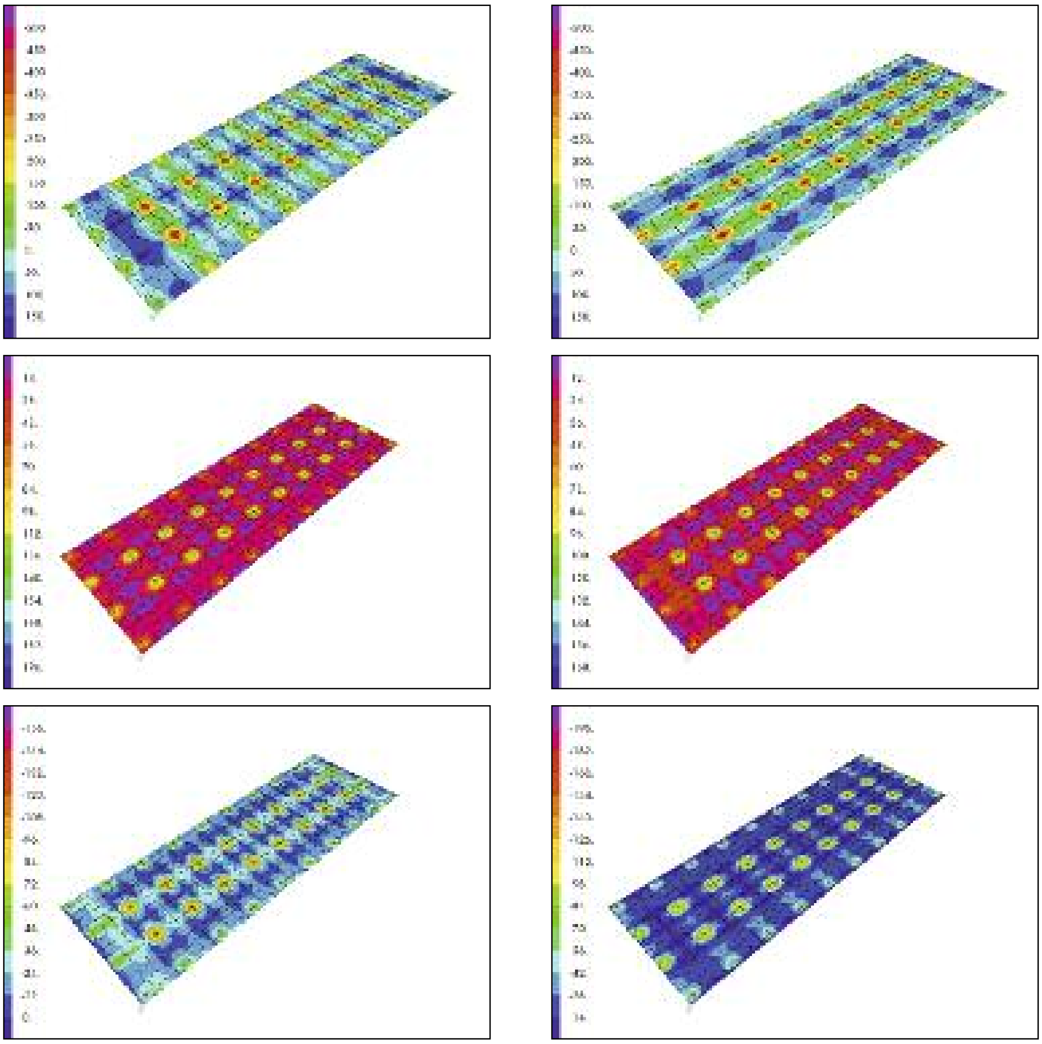


Fig. 17
Example of local reinforcement of the foundation plate at column bases.

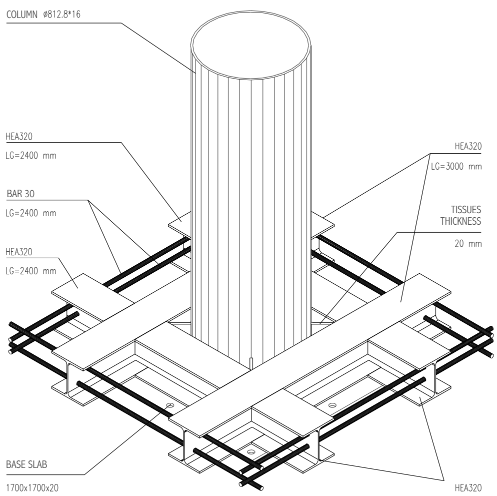


Fig. 18
Example of bending moment – axial action strength domain, for a section of plate (at columns centres).

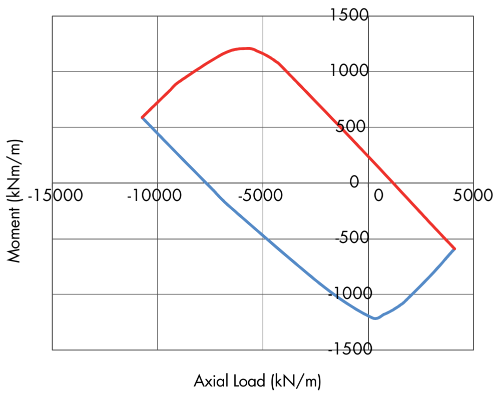


Fig. 19
Example of bending action on the isolated plate during bearing substitution at different locations.

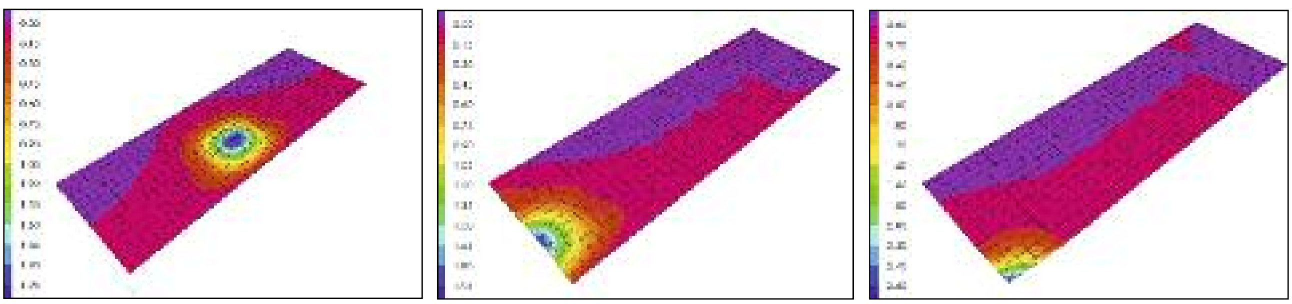


Fig. 20
Reinforcement in a foundation plate with concrete columns and steel columns with isolators on a casted plate.

Prescription for building design

As already mentioned, the final design of the home buildings was left to the bidders, to allow the use of any building technology. However, the specifications to which the projects would have anyway to conform needed to be defined as to assure an appropriate safety level to the global structural system.

The seismic demand was defined in terms of design acceleration of the building masses, calculated with reference to the maximum value of the ratio between base shear and weight of the building, obtained in the worst loading conditions, corresponding to those of a stiff building (**T** = 0.19 sec) with the lowest mass (1,500 t).

For analyses performed with accelerograms compatible with the design spectrum at a collapse limit state (SLC, return period ≈ 1,000 years), the base shear always resulted less than 0.11 times the weight of the building. It was therefore prescribed to assume a design acceleration equal to 0.1 g to verify the buildings at a life safety limit state (SLV, return period ≈ 500 years).

For the same conditions, the average inter storey drift resulted on the range of 0.1%, a value that certainly allows a full use of the buildings even after a high intensity event.

Together with these extremely simple design data, a series of prescriptions on the characteristics of the buildings needed to be defined, in order keep them within the parameters assumed for the analyses and therefore avoiding unexpected responses and jeopardizing the verification of plates, foundations and isolation system.

A summary of these prescriptions follows:

1. The load resulting from the building structures shall not induce in any element of the slab – foundation system local actions larger than those resulting from a uniformly distributed live load equal to 50 kN/m^2 (i.e. excluding the slab self weight).
2. The load distribution on the plates shall exclude concentrations potentially resulting in local collapses.
3. The maximum vertical action on a single bearing should be less than 2,800 kN, either for the seismic load combination and for the gravity combination at the ultimate limit state, including the weight of the plate.
4. Bearings shall not be subjected to tensile forces in any load case.
5. The main period of vibration of the building (considered fixed at the base) shall not exceed 0.5 seconds.
6. The eccentricity between centre of mass of the building and centre of mass of the plate shall be less than 5% of the total length of the plate (57 m) in the longitudinal direction, and less than 10% of the length of the plate (21 m) in the transversal direction.
7. The maximum seismic mass of the building alone (i.e. without considering the weight and loads of the slab), calculated including self weight, dead load and the fraction of live load to be considered for seismic verification shall be less than 2,100 t.
8. The buildings shall be designed in accordance with the technical code of 14/01/2008. It is accepeted to represent the horizontal load equivalent to the seismic action by means of a static force vector, to be applied to the building floors, according to equations given in the code, assuming a design acceleration Sd (T1) of 0.1 g.

3.1.5 Construction of the plates

As previously discussed, for the production of the plates, the ForCASE consortium has directly taken the role of general contractor, with calls for bids for excavations, supply of concrete (initially about 200,000 m^3, with peaks in delivery of more than 5,000 m^3 per day, self compacting and aerated), supply of welded wire meshes

Fig. 21
Rendering and floor plans of some buildings, proposed by the bidders.

(initially about 260,000 kN, in general with diameter 14 mm at 100 mm), supply of steel columns (initially 180,000 ton, diameter 800 mm), supply of isolators (initially 6,000 pieces, including assistance to positioning) and supply of casting forms (initially for about 336,000 m^2) and on-site assistance for reinforcement positioning and pouring of concrete. All quantities were later significantly increased, since the number of buildings passed from 150 to 184. The prices per unit obtained through bidding have been the following:

- Self-compacting concrete 82.55 €/mc
- Welded wire mesh 0.49 €/kg
- Steel columns 2.09 €/kg
- Isolators 1,427 €/piece
- Forms and on-site assistance 91.7 €/m^2

Contractors for the production of the plates with initial price and offers.

Bid	Contractor	Bid price	Price reduction	Contract price
Forms and on site assistance	GRUPPO BISON	15,078,609	12.25%	13,243,300
Forms and on site assistance	ZOPPOLI & PULCHER	13,686,737	9.80%	12,354,109
Forms and on site assistance	SACAIM	3,015,721	15.51%	2,551,007
Supply of concrete	COLABETON	9,000,000	8.00%	8,280,000
Supply of concrete	COLABETON	4,500,000	8.30%	4,126,500
Supply of concrete	COLABETON	4,500,000	8.80%	4,104,000
Supply of welded wire mesh	LA VENETA RETI	12,870,000	1.21%	12,714,000
Supply of steel columns	RTI EDIMO E TADDEI	20,384,700	5.32%	19,303,440
Supply of steel columns	CORDIOLI	20,384,700	9.81%	18,390,000
Supply of isolators	ALGA	4,160,000	10.63%	3,718,000
Supply of isolators	FIP INDUSTRIALE	3,200,000	9.84%	2,885,120
Supply of isolators	ALGA	2,240,000	12.50%	1,960,000
Excavation	CO.GE.FER.	3,394,340	27.37%	2,503,659
Excavation	ATI PRS	3,005,759	35.63%	1,981,054
Excavation	MIDAL	703,142	13.51%	612,011
Total		**120,123,709**	**12.56%**	**108,726,204**

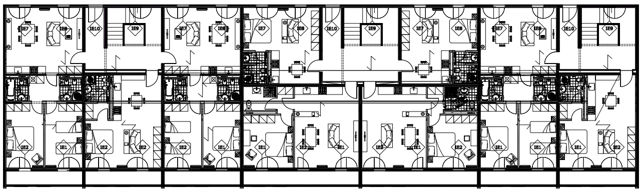
3.1.6 Construction of the buildings

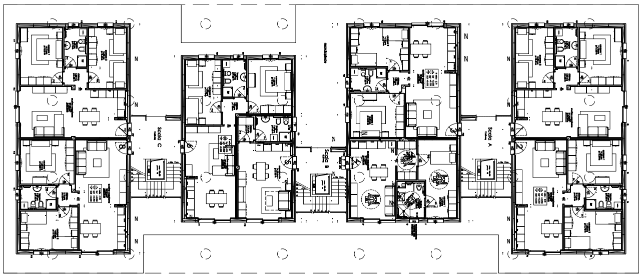
A public call for bids was launched for the construction of the buildings; including final design. The 150 buildings to be built were grouped in 30 lots, each one of 5 buildings, allowing a bidder to present a proposal for a maximum of 10 lots.

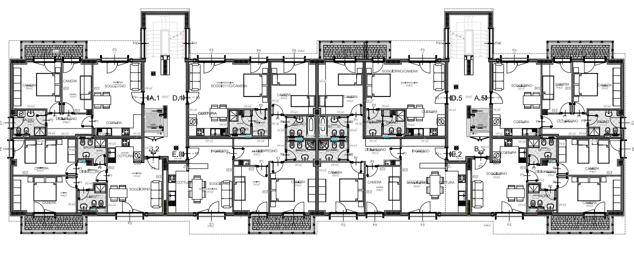
Depending on the final ranking of the offers, it might have been possible to have from a minimum of 3 contractors (in case the first 3 would each propose 10 lots) to a maximum number of 30 contractors (in case each one would have proposed 1 lot). The basic price for any lot of 5 buildings (about 160 covered parking spots, 3,000 m^2 of outside pavement and 9,000 m^2 internal living area) was fixed at 11 million euro. The evaluation of the proposals was essentially based on the proposed improvement of the minimum performance characteristics foreseen by the existing norms (that already represents a high standard). The maximum time allowed for completing each building from the availability of the upper plate was fixed at 80 days, a proposed reduction was also considered in the evaluation, together with a reduction of the proposed price.

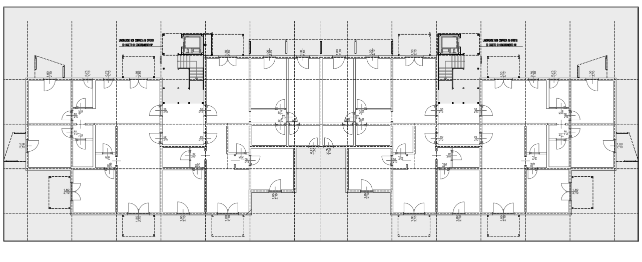
Following the presentation of the 58 proposals and an accurate review, 16 contractors were selected, with a total average amount per lot of about 10,500,000 euro, which means an offered price reduction of about 5%.

On a total of 150 buildings, timber structures were proposed for 75 (50%), concrete structures for 45 (30%) and steel structures for 30 (20%).









Contractor	Strucutre Material	Buildings Number	Price Per Building
Wood Beton Spa	Timber	5	€ 2,051,400
Rti Consorzio Stabile Consta S.C.P.A. – Sicap Spa	Precast Concrete	10	€ 2,027,342
Consorzio Etruria Soc.coop. A R.L.	Concrete	5	€ 2,090,000
Rti Impresa Costruzioni Giuseppe Maltauro Spa - Taddei Spa	Steel	25	€ 2,110,000
Rti Coge Costruzioni Generali Spa - Consorzio Esi	Concrete	5	€ 2,095,720
Rti Ing. Armido Frezza Srl-walter Frezza Costruzioni S.R.L.-archlegno Spa	Timber	5	€ 2,190,000
Meraviglia Spa	Timber	5	€ 2,089,123
Rti Eschilo Uno Srl/cogeim Spa/Alfa Costruzioni 2008 Srl	Steel	5	€ 2,115,080
Rti Iter Gestione E Appalti Spa-sled Spa-vitale Costruzioni Spa	Timber	20	€ 2,153,580
Ati Donati Spa/Tirrena Lavori Srl/ Dema Costruzioni Srl/Q5 Srl	Concrete	10	€ 2,024,000
Consorzio Stabile Arcale	Timber	5	€ 2,132,020
D'agostino Angelo Antonio Costruzioni Generali Srl	Concrete	5	€ 2,120,000
Orceana Costruzioni Spa	Timber	20	€ 2,120,000
Impresa Di Costruzioni Ing. Raffaello Pellegrini Srl	Concrete	10	€ 2,156,000
Cosbau Spa	Timber	10	€ 2,144,000
Rti Ille Prefabbricati Spa - Belwood Srl	Timber	5	€ 2,165,400
Total And Average Price		150	€ 2,099,900

Contractors, structure material, number of buildings offered and price per building.

3.1.7 Infrastructures, furniture, elevators, mechanical and electrical installations, green areas

To complete the project it was necessary to prepare and launch other 5 groups of bids, in order to satisfy various needs:

- The upgrading and integration of the external infrastructure (networks of any type) with the difficult problem of interacting with the construction sites. Twenty bids were released, one for each area of intervention, inviting companies located in Abruzzo and preferably in the province of L'Aquila. Five companies randomly sorted out were invited to bid for each site.
- The furniture and supplies necessary to immediately used the apartments. In this case a public competition was set up, on four lots of about 1,000 apartments each. The foreseen time to assemble the furniture on site was 6 days from the moment an apartment would be finished. 18 companies presented an offer, with the following four resulting winners: Deltongo Industrie spa, Mobilificio Florida srl, RTI Europea spa – P.M. International Furnishings srl – Martex spa and Estel Office spa. The average price reduction offered was about 34%, which corresponds to an average cost for the interior furnishing of an apartment of 9,500 euro. It has to be underlined that the specifics of the bid requested the highest possible standards also for the electrical and mechanical equipment included in the offer, such as dish washer, washing machine, tv set, etc.
- 309 elevators to connect the various floors of the buildings and 129 elevators to connect the buildings to the parking ground floor. This need derived from the specific choice of completely eliminating all potential architectonical barriers case, in excess of what compulsory for legal requirement. A call for bids was released for three lots of 146 elevators each; 12 companies participated in the competition. Marrocco elevators srl, ATI S.A.S. srl – Grivan Group srl, Schindler spa resulted winners with an average reduction of price of about 16%.
- The opportunity of producing electric energy on site, collocating photovoltaic panels on the roofs. An estimate of about 45,000 m^2 of roof surface was considered adequately exposed to sunshine and consequently another bid was released for the design, construction, management and maintenance of a photovoltaic system, capable of producing about 4,500 kW. The call for bid assumed that there should have been no cost

Fig. 22
Some completed buildings.

to the administration, and was based on technical merit and on one fundamental economical parameter, i.e. a yearly fee to be paid, as a percentage of the public incentives provided to favour the use of alternative, renewable energy sources. The winner and therefore contractor was Enerpoint spa, Ener Point Energy Srl and Troiani & Ciarocchi Srl., who offered to refund 9,01% of the incentives.

- Finally, two last calls for bids were launched to complete the green areas, simply grouping the eastern and western construction sites. The offers should obviously include land preparation, grass, bushes and trees, walking and cycling paths, but also irrigation and drainage systems, external furniture, sport and leisure fields. 19 companies participated in the bid and contractors were selected on cost and on evaluation of landscape beauty, environmental sustainability and maintenance and management characteristics of the offers. The selected contractors were 3A Progetti S.p.a, which lowered the estimated price of 39% and the Sestante Consortium, that managed to offer a 35,16% reduction.

3.1.8 Work management, quality control, safety measures

The extremely limited time available for the completion of the project required an extreme level of control and programming, with a continuous flow of information between engineering work management and construction companies and daily reports and checks.
A coordination and management system was therefore set up, focusing on the definition of priorities and of the main activities consequently required and on the identification of potentially critical elements and work phases that could threaten the fulfilment of the programmed time schedule.
As previously discussed, the work activities and their management and control were organised in five sectors, corresponding to production of the plates, buildings (including interior design and furniture), mechanical and electrical installations, infrastructures roads and green areas. For each technical sector a technical coordination structure was defined with a responsible for programming, coordination with the construction companies and management of works. The general timeline of the works was accordingly subdivided into the same five sectors. Daily updates on the work progress and comparison with the time planning guaranteed that each sector was closely monitored in terms of work progress, as well providing all technical personnel with a an overview of the general picture, fundamental to manage the coordination between different sectors. The graphical visualization of the daily progress of the works resulted to be particularly useful for a rapid interpretation of the complexity of the data that needed to be managed.
An idea of the large quantities of materials and labour that needed to be managed, can be obtained by considering the example of the foundation and isolation system, that on a daily basis needed an average concrete supply of the order of 5,000 m^3, welded meshes and reinforcing bars for about 10,000 kN, about 200 steel columns (with a diameter of 800 mm), to be provided in general in 20 different construction sites. The efficiency of the team that was set up to program and coordinate the activities, allowed such a proper and precise forecasting of the work progress that all construction sites proceeded always on time and actually all works were completed ahead of time, despite of the difficulties





inherent in the number of workers (more than 8,000 in some phases) and in the complex interaction between different work activities. An example of the time schedule programmed for the construction of the two slabs systems, with foundation and isolation, can be summarised as follows:

Fig. 23
Work in progress and completed works (on the previous page).

Site preparation	2	days
Excavation	2	days
Positioning of reinforcement (foundation slab)	2	days
Concrete casting (foundation slab)	2	days
Positioning of columns	1	day
Positioning of the isolating devices	1	day
Formwork and positioning of reinforcement for the upper slab	3	days
Concrete casting (upper slab)	1	day
Removal of the formwork	3	days
Total time for the construction of foundation and isolation plates	**17**	**days**

Finally, the great efficiency of the team in charge of controlling all aspects of safety in the work process should be noted. The extremely detailed and continuous checks allowed the completion of hundreds of millions of euro worth of work in just a few months without any notable accident and with the appreciation of all external controlling institutions, from those aimed to assure workers health to the unions.

SUMMARY OVERVIEW

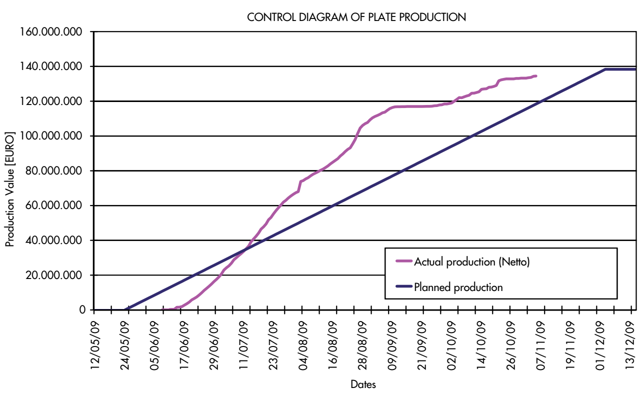
Summary overview: 25 october 2009

Construction site (number)	opened	20	of	20	100%
Concrete (square m)	casted	294,023	of about	300,000	98%
Framework (piles)	positioned	29298	of about	32871	89,1%
Pillars (number)	positioned	7288	of	7368	98,9%
Isolators (number)	positioned	6328	of	7368	85,9%
Plates (number)	placed	183	of	183	100%
Slabs (number)	casted	178	of	183	97,3%
Plates (number)	delivered	164	of	183	89,6%
Buildings (number)	under construction	161	of	183	88,0%
Buildings (number)	completed	59	of	183	32,2%
Buildings (number)	furnished	50	of	183	27,3%
Buildings (number)	inhabited	41	of	183	22,4%

Buildings delivered to inhabitants 23/10/2009; for about 320 in habitants

Extension from 150 to 183 buildings — Unsettled inhabitants about 16.000

Fig. 24
Example of a global daily overview form.



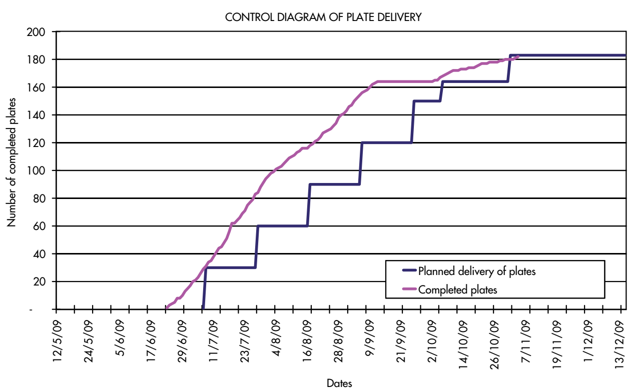
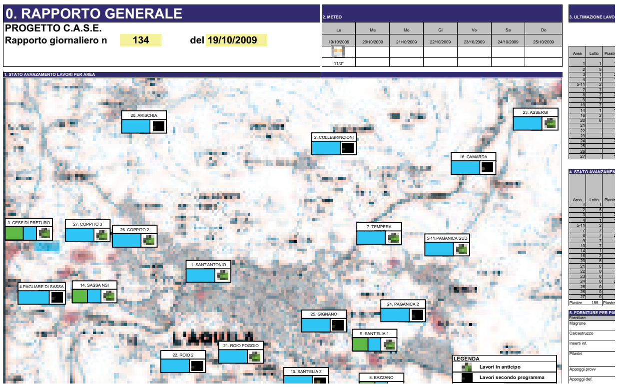


Fig. 25
Example of a production summary overview daily form (25 October, general overview on the left, production and delivery of plates on the right).



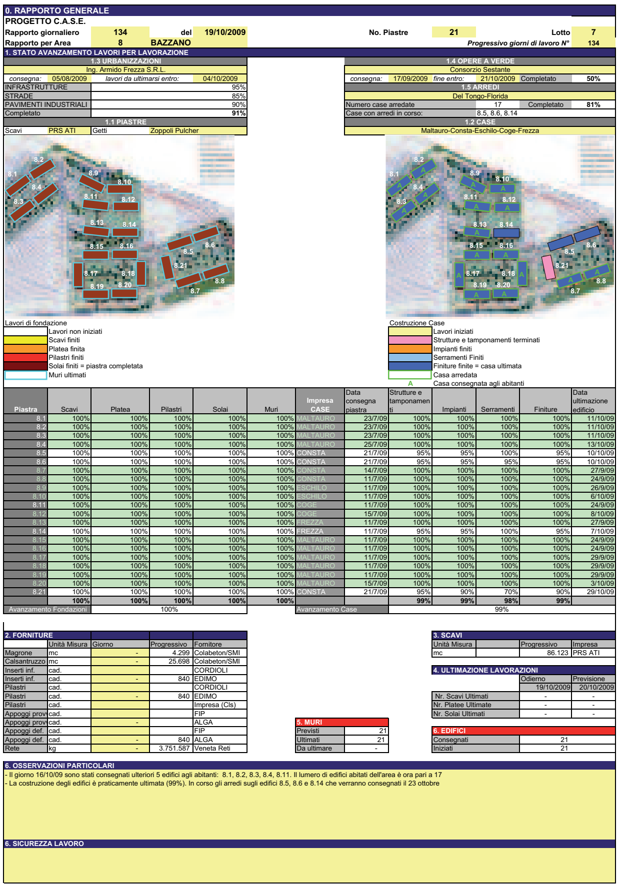


Fig. 26
Example of a daily report on the general development of the project works (19 October).

Fig. 27
Example of a daily report on the general developments of the works in a specific area (19 October).

3.1.9 The costs

The total cost of the project is split in the table below, considering the different category of work and giving the average cost per building, per apartment and per square meter of living space. The total cost of 655 million euro refers to a total of 164 buildings, while 150 were foreseen at the starting of the project and 184 were actually built at the end. Applying a criterion of linear proportion it can be inferred that the original 150 buildings would have cost 599 million euro, which is in line with the 700 million that were initially estimated, since the sums indicated do not include the cost for land expropriation and V.A.T. The cost of the double slab foundation system is compensated to significant extent by the value of the covered parking spots, each one of them have the size of a large garage box (6 by 3 meter). The number boxes exceed that of the apartments. It is thus reasonable to assume that the real cost of the foundation system is actually a fraction of that indicated in about 30,000 € per apartment. If a fraction of 30% would be assigned to the foundation itself, the cost per square meter of the living space should result to be less than 1,400 €, including foundations: a reasonable value, especially considering the compressed time of construction, that was made possible by a continuous work over the 24 hours, with three turns of 8 hours each, day and night and considering as well the very high quality of the buildings for aspects related to energy consumption, environment and detailing quality.
It is interesting to note that the seismic isolation cost only about 1,5% of the total, or rather just a bit over 2% when only the building cost is considered. The modest cost of general and technical activities has to be noted, made possible by the way the project was managed, extensively discussed in the previous sections. The real share of the technical costs of the ForCASE consortium (design, management, security, etc) has been around 8 million euro, i.e. not much more than 1% of the total cost. The costs of the furniture includes everything, from TV sets to bed sheets.

3.1.10 The future

At the moment this article is being completed (September) the last 20 buildings are being constructed, with a significantly lower cost because they are built in already inhabited areas. The decision of the Civil Protection Department to build additional houses was motivated by upgraded in the population census. It is foreseen that these buildings will be delivered within February 2010, with the possibility of notable antic-

	Total cost (million)	Average cost per building (164,29)	Average cost per house (4084)	Average cost per m² of living area	Weight percentage
Buildings					
Excavations and foundations	€ 122	€ 742,589	€ 29,873	€ 413	18.63%
Seismic isolation	€ 10	€ 60,868	€ 2,449	€ 34	1.53%
Apartments	€ 359	€ 2,185,160	€ 87,904	€ 1,214	54.81%
Total buildings	**€ 491**	**€ 2,988,618**	**€ 120,225**	**€ 1,660**	
Infrastructure and complementary works					
Infrastructure and external works (sustaining walls, drainage, roads, sewage, water adduction, gas and electric energy, etc.)	€ 73	€ 444,336	€ 17,875	€ 247	11.15%
Green and urban landscape	€ 13	€ 79,128	€ 3,183	€ 44	1.98%
Elevators and ramps	€ 12	€ 73,042	€ 2,938	€ 41	1.83%
Furniture, apparels and cleaning	€ 46	€ 279,993	€ 11,263	€ 156	7.02%
General and technical costs	€ 20	€ 121,736	€ 4,897	€ 68	3.05%
Total	**€ 655**	**€ 3,986,853**	**€ 160,382**	**€ 2,215**	**100.00%**

Parametric costs of the whole intervention, based on 164,29 equivalent buildings, v.a.t. not included.

ipation if the meteorological circumstances should be favourable.
The delivery of the houses started Tuesday 29 September with about 500 apartments and will continue at a pace of approximately 300 apartments a week. The property of the buildings will be eventually assigned to the city of L'Aquila who will be responsible for the management and maintenance based on pre-defined procedures, specified in detail in the project documents. Political and economical choices, with relation to the progress in the repair, strengthening and reconstruction of the buildings damaged in the historical centre and in the city outskirt, will drive the decision on rent costs and use of the new villages.
The users of the houses are being carefully selected jointly by the city of L'Aquila and the DPC, taking into account the preferences expressed by the homeless people, parameters connected to the family situation (number of components, age, economical capacity, etc.) and the localisation of the original place of living. A prerequisite to be considered is that a family previous home should have been classified in the category '*non easily to be repaired*' (type E and F in the classification of damage).
The houses will anyway become part of the city's heritage and in the future it will be therefore possible to reuse them to host vulnerable categories of population (such as the elderly people) or to host students, a need particularly relevant in L'Aquila, where a significant fraction of the 25,000 students come from other regions.
In the near future the availability of student housing at a controlled price could become a relevant peculiarity of the university, modifying its attraction capacity in a positive way.

3.1.11 Tests and verification on the isolation system

About 400 isolating devices were tested in the laboratory, at real scale, real velocity levels and various axial load levels, dynamically controlled. Significant variation of the friction coefficient were evident, as a function of the axial force and of the velocity. For what concerns axial force, the dynamic friction coefficient varied from about 2.5% to about 5% for one producer, and from about 5% to about 12% for the other one. The static friction coefficient was in the range of twice the dynamic value in the first case and only slightly large than the dynamic one in the second case.
In addition, eleven buildings were dynamically tested on site, moving the upper plate with respect to the lower one using two hydraulic actuators. Displacements of 150 - 200 mm were imposed at speeds of about 150 - 200 mm/s, depending on the weight of the building.

The available data are extraordinary, and cannot even be summarised here. However, it is interesting to note that the larger than expected friction coefficient increase the equivalent damping of the isolation system, consequently significantly reducing the displacement demand. On the opposite, it is clear that the maximum base shear at the building level results to be larger than expected and depends essentially on the static friction coefficient, since during the response a relative movement at the device level takes place only when the local shear force exceeds the limiting friction capacity.

3.1.12 Conclusions on structural performances
Thousands non linear analyses of the buildings, performed using the actual experimental data, allowed to estimate the maximum base shear that could be attained in each case, in general lower than 20 % of the weight of the building. Such value was always acceptable considering a low damage performance level, consistent with the full use of the buildings after the design 500 years return period event. The small change in the base shear for larger events and the very small interstorey drift demand, together with the displacement capacity of the isolating system, largely in excess of any reasonable demand, make the buildings essentially insensitive to any potential earthquake.

Forecast of the number of apartments and beds available in function of the foreseen completion period (forecast of September 22nd, including the twenty buildings that had just been added, of which forecasts are cautious).

Consorzio ForCASE — [illegible]

Data poss. consegna	Numero edifici		POSTI LETTO 2	3	4	5	6	7	8	Totali
28/09/2009	19	Appartamenti ->	62	124	8	221	12	40	0	467
		Abitanti ->	124	372	32	1.105	72	280	0	1.985
03/10/2009	9	Appartamenti ->	33	33	10	140	8	0	0	224
		Abitanti ->	66	99	40	700	48	0	0	953
10/10/2009	13	Appartamenti ->	47	61	17	178	14	6	0	323
		Abitanti ->	94	183	68	890	84	42	0	1.361
17/10/2009	12	Appartamenti ->	29	89	4	148	4	24	0	298
		Abitanti ->	58	267	16	740	24	168	0	1.273
24/10/2009	7,75	Appartamenti ->	12	38	10	128	0	0	0	188
		Abitanti ->	24	114	40	640	0	0	0	818
31/10/2009	10	Appartamenti ->	39	53	6	114	10	22	0	244
		Abitanti ->	78	159	24	570	60	154	0	1.045
07/11/2009	6,75	Appartamenti ->	8	36	6	108	1	5	0	164
		Abitanti ->	16	108	24	540	6	35	0	729
14/11/2009	7	Appartamenti ->	9	50	23	55	3	23	0	163
		Abitanti ->	18	150	92	275	18	161	0	714
21/11/2009	13,75	Appartamenti ->	29	56	37	200	5	5	0	332
		Abitanti ->	58	168	148	1.000	30	35	0	1.442
28/11/2009	21,75	Appartamenti ->	14	137	40	315	3	15	0	524
		Abitanti ->	28	411	160	1.575	18	105	0	2.297
06/12/2009	13,75	Appartamenti ->	29	87	6	182	3	23	0	330
		Abitanti ->	58	261	24	910	18	161	0	1.432
12/12/2009	17	Appartamenti ->	31	113	34	221	3	14	0	416
		Abitanti ->	62	339	136	1.105	18	98	0	1.758
19/12/2009	13	Appartamenti ->	27	87	27	183	0	0	0	324
		Abitanti ->	54	261	108	915	0	0	0	1.338
24/01/2010	5	Appartamenti ->	20	140	0	0	0	0	0	160
		Abitanti ->	40	420	0	0	0	0	0	460
07/02/2010	5	Appartamenti ->	20	140	0	0	0	0	0	160
		Abitanti ->	40	420	0	0	0	0	0	460
21/02/2010	5	Appartamenti ->	20	140	0	0	0	0	0	160
		Abitanti ->	40	420	0	0	0	0	0	460
07/03/2010	5	Appartamenti ->	20	140	0	0	0	0	0	160
		Abitanti ->	40	420	0	0	0	0	0	460
Totale generale	183,75	Appartamenti ->	449	1.523	228	2.193	67	177	0	4.637
		Abitanti ->	898	4.569	912	10.965	402	1.239	0	18.985

Those who have contributed to the success of the C.A.S.E. project:

Department of Civil Protection
Giacomo Aiello (**legal responsible**),Emilia Aloise, Giovanna Andreozzi, Enrico Ardito, Vincenzo Ardito, Arianna Bertelli, Mariano Bonvegna, Angelo Borrelli (**administration responsible**), Fabrizio Bramerini, Cristina Capriotti, Maria Teresa Cartolari, Mario Cera, Claudia Ciccone, Pietro Colicchio, Alessandra Conti, Marco Conti, Maria Laura Conti, Chiara D'angelo, Antonella De Felice, Giulio De Marco, Giovanni Di Achille, Giovanni Di Mambro, Mauro Dolce (**technical responsible**), Riccardo Fabiani, Maria Cristina Ferroni, Salvatore Fiengo, Claudia Fiore, Mariasilvia Gianneramo, Beatrice Guerra, Gerarda Iannarone, Federica La Chioma, Luisa Marinaro, Lucia Palermo, Francesca Paneforte, Ada Paolucci, Roberto Pesolillo, Giancarlo Piccione, Patrizia Picuti, Immacolata Postiglione, Giuseppina Sementilli, Vincenzo Spaziante (**general coordinator**), Tiziana Tarduini, Vergilio Tidei, Fabiola Toni, Angelo Vici.

CASE Consortium
Fabio Aldrovandi, Francesco Ambrosi, Francesco Amici, Maurizio Ardingo (**responsible for construction safety measures**), Luciano Baglione, Giovanni Bastianini, Paolo Battegazzore, Giuliano Bellini, Maria Teresa Dolores Bertelegni, Federica Bianchi, Saverio Bisoni, Gaia Boggioni, Filippo Bonali, Barbara Borzi, Maria Benedetta Bossi, Matteo Bottari, Vittorio Bozzetto, Roberto Brandimarte, Piero Burba, Maurizio Calderari, Andrea Caligari, Maura Castellani, Gian Michele Calvi (**project leader, designer and construction director**), Salvatore Caroli, Christian Caroli, Paolo Caroli, Francesco Ceribelli, Antonio Coccia, Andrea Colcuc, Oliviero Comand, Massimiliano Cordeschi, Filippo Dacarro, Michele D'Adamo, Alberto Damiani (**responsible for building construction**), Pietro Damiani, Edi Danielis, Simonetta Di Nicola, Maurizio De Santis, Pasquale Di Marcantonio, Dante Di Marco, Stefano D'Ottavio, Ettore Fagà, Mario Fanutti, Carlo Florio, Pierluigi Fontana, Fabrizio Frau, Renato Fuchs (**organisation coordinator**), Nicola Gallina, Marco Gasperi, Fabio Germagnoli, Federico Gianoli, Daniele Gimnetti, Sergio Giordano, Stefano Grasso, Carlo Lai, Massimo Lardera (**responsible for infrastructure**), Ignazio Locci, Giuseppe Lombardi, Mauro Maganetti, Giovanni Magenes, Claudio Maggi, Carlo Magni, Fabrizio Magni, Michele Magnotti, Gabriele Mantini, Antonio Marcotullio, Paola Marotta, Sara Martini, Emanuele Meago, Paola Migliazza, Enrico Misale, Marta Molinari, Federico Monutti, Matteo Moratti (**site responsible for structures**), Vincenzo Pane, Vincenzo Paolillo, Alessandro Papale, Carmine Pascale, Pierluigi Pascale, Moreno Pavan, Fausto Pedetta Peccia, Gianfranco Peressutti, Edoardo Peronace, Michele Pescina, Paolo Petrucco (**site responsible for plates and infrastructure**), Piero Petrucco, Nereo Pettenà, Dario Pietra, Roberto Pitolini, Federica Polidoro, Alessandro Pollini, Stefano Pozzi, Salvatore Provenzano, Bruno Quadrio, Nadia Rizzardi, Enzo Rizzi, Fabio Roiatti, Cristiana Ruggeri (**responsible for mechanical and electrical installations**), Gaetano Ruggeri, Mario Rusconi, Daniele Sambrizzi, Valentina Scenna, Matteo Schena, Michele Schiabel, Paolo Scienza, Fabiola Sciore, Roberto Scotti, Domenico Sgrò, Martino Signorile, Danilo Marco Siviero, Luigi Spadaro, Davide Tagliaferri, Piergiuseppe Tamburri, Alessandro Tosello, Stefan Trenkwalder, Roberto Turino (**site responsible for buildings**), Diego Urbani, Marco Vecchietti, Paolo Verri, Stefano Vitalini (**site responsible for plates**), Roberta Viviani

Checker team, administrative aspects
Giovanna Andreozzi, Maria Laura Conti, Alessandra Conti, Michele D'adamo, Giovanni Di Mambro, Salvatore Fiengo, Giorgio Grossi, Emilia Aloise, Mariano Bonvenga, Carlo Bordini, Cristina Capriotti, Maria Teresa Cartolari, Carluccio Codeghini, Fabio Compagnoni, Dario Compagnoni, Massimo Criscuolo, Antonella De Felice, Giuseppe Fasiol, Maria Cristina Ferroni, Arturo Furlan, Achille Gentile, Alessandro Greco, Gerarda Iannarone, Giuseppe Ianniello, Giovanni Infante, Ettore Iorio, Paolo Marchesi, Luca Pagani, Lucia Palermo, Roberto Pesolillo, Salvatore Provenzano, Rosario Romano, Gianni Strazzullo, Fabiola Toni, Daniela Ursino, Michele Villani

Checker team, structures
Edoardo Cosenza, Gaetano Manfredi, Claudio Moroni, Paolo Pinto (**President**), Paolo Zanon (assistenti: Massimo Acanfora, Claudio D'Ambra, Antimo Fiorillo)

Companies and organisations
Excavations: CO.GE.FER. s.p.a.; Midal s.r.l.; P.R.S. Produzione e Servizi s.r.l. ***Concrete:*** Colabeton s.p.a.; Società Meridionale Inerti SMI s.r.l. ***Steel reinforcement:*** La Veneta Reti s.p.a. ***Steel columns:*** A.T.I. Edimo Metallo s.p.a. /Taddei s.p.a.; Cordioli & C. s.p.a.; ***Formwork and assistance:*** Consorzio Edile C.M. Gruppo Bison; Sacaim s.p.a.; Zoppoli & Pulcher s.p.a. ***Isolators:*** Alga s.p.a.; FIP Industriale s.p.a. ***Buildings:*** A.T.I. Consorzio Stabile CONSTA s.c.p.a./Sicap s.p.a.; A.T.I. Donati s.p.a./Tirrena Lavori s.r.l./Dema Costruzioni s.r.l./Q5 s.r.l.; A.T.I. Eschilo Uno s.r.l./COGEIM s.p.a./Alfa Costruzioni 2008 s.r.l.; A.T.I. Ille prefabbricati s.p.a./Belwood s.r.l.; A.T.I. Impresa Costruzioni Giuseppe Maltauro s.p.a./Taddei s.p.a.; A.T.I. Iter Gestione e Appalti s.p.a./Sled s.p.a./Vitale Costruzioni s.p.a.; A.T.I. COGE Costruzioni Generali s.p.a. /Consorzio Esi; Consorzio Etruria s.c.a.r.l.; Consorzio Stabile Arcale; Cosbau s.p.a.; D'Agostino Angelo Antonio Costruzioni Generali s.r.l.; Impresa di Costruzioni Ing. Raffaello Pellegrini s.r.l.; Meraviglia s.p.a.; Orceana Costruzioni s.p.a.; R.T.I. Ing. Armido Frezza s.r.l./Walter Frezza Costruzioni s.r.l./ Archilegno s.r.l.; Wood Beton s.p.a. ***Furniture:*** Del Tongo Industrie s.p.a.; Estel Office s.p.a.; Mobilificio Florida s.r.l.; R.T.I. Europeo s.p.a./ PM.International Furnishing s.r.l. ***Infrastructure:*** CO.M.AB. Appalti Pubblici e Privati s.n.c.; Codimar s.r.l..; Codisab s.r.l.; Conglomerati Bituminosi s.r.l.; Facciolini s.r.l.; G.C.G. s.r.l.; I Platani s.r.l.; Impresa Edile Di Cola Michele; Ing. Armido Frezza s.r.l.; Molisana Inerti Conglomerati s.r.l.; Produzione e Servizi s.r.l.; Ridolfi Idio e Figli s.r.l.; San Giovanni Inerti di Pietro Mascitti s.r.l.; Valentini Costruzioni s.a.s.; ***Elevators:*** Marrocco elevators s.r.l., ATI S.A.S. s.r.l./Grivan Group s.r.l., Schindler s.p.a.; ***Photovoltaic panels:*** R.T.I. Ener Point s.p.a./Ener Point Energy s.r.l./Troiani & Ciarrocchi s.r.l.; ***Green areas:*** R.T.I. 3a Progetti/Gsa s.r.l./O.Ci.Ma. s.r.l./Bellomia-Sebastianini-Euroengineering s.r.l., Consorzio Sestante. ***Demolition:*** CODISAB SRL, A.S.M. s.p.a.; ***Connections to external pipeline networks:*** ENEL Rete Gas, ENEL Energia, GranSasso Acqua.1

References

1. NTC (2008) - *Norme Tecniche per le Costruzioni*, D.M. 14/01/2008, Gazzetta Ufficiale 04/02/2008, Italia.
2. Zayas V., Low S. (1990) - A Simple Pendulum Technique for Achieving Seismic Isolation, *Earthquake Spectra*, Vol. 6, No. 2.
3. Almazan J.L., De la Llera J.C. (2002) - Analytical model of structures with frictional pendulum isolators, *Earthquake engineering and structural dynamics*, Vol. 31, 305-332.
4. Calvi G.M., Ceresa P., Casarotti C., Bolognini D., Auricchio F. (2004) - Effects of axial force variation on the seismic response of bridges isolated with friction pendulum systems, *Journal of Earthquake Engineering*, Vol. 8, SI1, 187-224.
5. Christopoulos C., Filiatrault A. (2006) - *Principles of Passive Supplemental Damping and Seismic Isolation*, IUSS Press, Pavia.
6. Priestley M.J.N., Calvi G.M. (2002) - Strategies for repair and seismic upgrading of Bolu Viaduct 1, Turkey, *Journal of Earthquake Engineering*, Vol. 6, SI1, 157-184.
7. Tsai C.S. (1997) - Finite element formulations for friction Pendulum seismic isolation bearings, *International Jour. for Num. Methods in Engineering*, Vol. 40, 29-49.
8. Wang Y., Chung L.L., Liao W.H. (1998) - Seismic response analysis of bridges isolated with friction pendulum bearings, *Earthquake engineering and structural dynamics*, 27, 1069-109.
9. Priestley M.J.N., Calvi G.M., Kowalsky M.J. (2007) - *Displacement based design of structures*, IUSS Press, Pavia.
10. Crowley, H. and Pinho R. (2004) - Period-height relationship ofr existing European reinforced concrete buildings, *Journal of Earthquake Engineering*, Vol. 8 (SP1) - 93-120.
11. Crowley H., Stucchi M., Meletti C., Calvi G.M., Pacor F. (2009) - Uno sguardo agli spettri delle NTC08 in relazione al terremoto de L'Aquila, *capitolo 1.7 in questo volume.*
12. AA.VV. (2007) - Definizione dell'input sismico sulla base degli spostamenti, progetto S5 INGV-DPC, http://progettos5.stru.polimi.it.
13. Comité Européen de Normalisation, Eurocode 8 part 2 (2006) - prEN1998-2, CEN, Brussels.

Here and in the next pages, some pictures of the completed buildings areas.