RELEVANT ITALY-ALGERIA COOPERATION PROJECT ON THE APPLICATION OF ADVANCED SEISMIC PROTECTION TECHNIQUES

A. Dusi[1] M. Mezzi[2] H. Azzouz[3]

[1] *Managing Director, Numeria Consulting, Cremona. Italy*
[2] *Professor, Dept. of Civil and Environmental Engineering, University of Perugia, Perugia. Italy*
[3] *PDG, Organisme National de Contrôle Technique de la Construction, CTC-Chlef, Chlef. Algeria*
Email: dusi@numeria-eng.it, m.mezzi@unipg.it, azzouzhamid2001@yahoo.fr

ABSTRACT:

A research project concerning the seismic protection of constructions has been included among the "relevant projects" of the scientific and technological protocol between Italy and Algeria. The project has been selected by a joint Commission of the Ministry of Foreign Affairs of the two countries and is co-funded by the Italian Ministry of Research and University. The research activities are aimed at improving the basic knowledge, the design procedures, the application systems, as well as the experimental tools of Seismic Isolation in order to promote its use in the Algerian current design practice for either new constructions and the seismic retrofitting of the existing ones. The main goals of the research project are: 1) dissemination of the knowledge in the seismic protection advanced techniques among researchers and designers; 2) layout of a laboratory for devices' full scale testing; 3) education and training of technicians in the use and design of new seismic protection system; 4) contribution to the drafting of guidelines (compatibles with the existing Algerian seismic code and the usual design procedures) for the design of base-isolated buildings. The bilateral collaboration is motivated by the fact that Italy is a world-wide leading country in the application and production of devices for Seismic Isolation and has high scientific and a technological know-how; on the other hand, Algeria is a developing country characterised by elevated seismic risk where the demand for modern antiseismic design is increasing fast. Huge programs of building development are planned in Algeria, mainly in seismic areas; this suggests the use and proper application of seismic protection techniques with a high benefit-cost ratio, like Seismic Isolation. The paper gives an overview of the research project by highlighting the innovative methodological approach and reports on the results so far obtained.

KEYWORDS: Seismic isolation, base isolation, vulnerability reduction

1 INTRODUCTION

Modern anti-seismic techniques, which includes seismic isolation (SI) and passive energy dissipation (ED), are an excellent system to achieve effective seismic protection of both new and existing structures; though relatively new, they can be considered fully mature and have been widely applied, all over the world, to buildings, bridges, industrial plant and equipments.

Base isolation is a design technique that reduces the force demand on structures by isolating them from the damaging effect of the ground motion. It functions primarily by lengthening the period of the structure. This approach contrasts with conventional design schemes that rely on inelastic action of various structural elements to dissipate earthquake energy. The isolation alternative reduces the force demand on the structure and thereby limits inelastic deformation; it provides a level of performance well beyond the normal code requirements with potential for substantial life-cycle cost reduction. In contrast to conventional technology, seismic isolation also offers the possibility of protecting the contents and secondary features (such as cladding and equipments) of the building because seismic forces transmitted to the structure are strongly reduced, thus also enhancing the safety of occupants and allowing for continuous use of the structure, even after a major seismic attack.

Research activities reported in this paper focus on the dissemination, improvement and application of the theoretical background, design approaches and procedures, technological aspects and testing procedures with the aim of promoting a correct use of BI as practical tool to protect ordinary and strategic building in medium to

high seismicity Algerian areas. The peculiar characteristics of SI makes it attractive for applications to reinforced concrete framed structures and masonry buildings; furthermore, SI can successfully be adopted for the retrofitting of existing structures, by, generally, limiting the works at the foundation level thus avoiding extensive, and often expensive, strengthening of the superstructure.

2 THE PROJECT

The bilateral co-operation, set up within the framework of the first Executive Protocol foreseen in the 2006-2009 Cultural, Scientific and Technological Agreement between Italy and Algeria, offered substantial opportunities for exchanging experience ad information. From one side, Italy, being a world-leading country in the SI application and devices' manufacturing, owns advanced scientific and a technological know-how. From the other side, Algeria, as a rich developing country characterised by elevated seismic risk, demands for modern antiseismic design with a high benefit-cost ratio, like SI: as a matter of a fact, in Algeria nowadays wide programs of housing development, often located in high seismicity zones, are running, not to mention the huge investments for the constructions of new highways and railways and the need of seismically protect strategic industrial plants and equipments. Under these conditions, a "large relevance" research project was proposed, titled "Development and application of the advanced techniques for the seismic protection of constructions" with a total budget of approximately € 250000. The project was approved and admitted to co-funding. It started in April 2007 and will have a duration of 36 months.

2.1 Main objectives of the project

As previously mentioned, the research activities are aimed at improving the basic knowledge, the design procedures, the application systems, as well as the experimental tools of (SI) in order to promote its use in the Algerian current design practice for either new constructions and the seismic retrofitting of the existing ones. The main goals of the jointly research project are:

- protecting citizens and infrastructures in the expanded and densely populated Algerian areas from earthquake risk;
- seismic protection advanced techniques knowledge dissemination among the selected target group of stake-holders, researchers, designers and end-users;
- definition of specific testing performance requests and layout of an Algerian laboratory for SI devices' full scale testing;
- education and training of Algerian technicians in the use and design of new seismic protection system;
- contribution to the drafting of guidelines, compatibles with the existing Algerian seismic code and the relevant design procedures, for the design of base-isolated buildings.

2.2 Working methodology

Project activities are organized in a series of consistent working tasks that can be grouped into three main work packages, each one focussing on a specific research aspect, described in the following. The partners, by combining their experiences and practices, will produce an enriched methodology: within each working task, the involvement of the Italian and Algerian partners is varying thus reflecting their specific competences.
It is envisaged that the proposed approach shall enable an effective information transfer and a reduction of the seismic vulnerability of buildings and infrastructure throughout Algeria.

2.2.1 Work package 1: problem definition and data collection

Through a coordinated approach, in the first 9 months of the project, the following activities will be carried out:

- selection and analysis of Algerian typical structural configurations, materials and construction technologies for new and existing buildings and structures in Algerians medium to high seismicity areas;

- definition of the performance needs for optimal seismic protection of the identified structural configurations and selection of the most effective SI systems amongst those available on the market;
- computer aided design approach and software evaluation with emphasis on the capabilities of correctly reproducing the actual SI devices characteristics;
- preparation and running of introductory workshops dedicated to decision makers and technicians; dissemination and exploitation activities will also include presentations of the SI technique to mass-media.

2.2.2 Work package 2: definition of design procedures, demonstration activities and contribution to the standards

Activities, foreseen for a duration of 21 months with some overlapping with those of Work package 1 and 3, will concentrate on:

- definition of specific design procedures for the application, within the Algerian context, of the SI techniques;
- drafting of guidelines, compatibles with the existing Algerian seismic code and relevant design procedures, for the design of base-isolated structures;
- implementation of demonstration activities and design of pilot applications;
- preparation of training material and organisation of technical workshops for the training of Algerian engineers in the application of SI concepts. It is envisaged that a number of the training material leaflets and reports will be produced and edited with an aim of not only serving as a means of results dissemination but also actually becoming valid and effective training and guidance tools, to be used by relevant professionals.

2.2.3 Work package 3: technological aspects

Twelve months efforts within the project activities will be devoted to the:

- definition of relevant acceptance and qualification tests on SI selected devices;
- definition of performance requirements and layout of an Algerian laboratory for SI devices' full scale testing;
- organisation of a final workshop for the presentation of the main project results. This event is foreseen at the end of the project and will constitute a major instrument for dissemination and training, since it is aimed at spreading the up-to-date and effective guidelines and recommendations produced in the project.

2.3 Project partnership

As described above, the rationale and mission statements of the project call for an integrated, multi-disciplinary, holistic and articulated project partnership, with expertise in the SI techniques and proven knowledge of the Algerian context. Therefore, the project team features the presence and involvement, from either the Italian and Algerian side, of leading academic and research institutions as well as industrial partners.
The overall scientific project coordination is under the responsibility of two members, one for each participating country, namely the Dept. of Civil and Environmental Engineering (DICA) of the University of Perugia for the Italian side and the "Organisme National de Contrôle Technique de la Construction" (CTC-Chlef) for the Algerian side.
The Dept. of Civil and Environmental Engineering of the University of Perugia has several years experience in SI research related activities and design, experience documented by a number of scientific publications. The Organisme National de Contrôle Technique de la Construction (CTC-Chlef) is an institution of high technological competences in the field of construction techniques, design and construction review and control, material testing. In addition to the two leading partners, the project partnership takes advantage of the contribution of the following members:

- Numeria Consulting srl – Italy, a high-tech oriented private company with a worldwide experience in the

design and testing of SI systems as well as in the coordination of international research projects;
- TARRC (Tun Abdul Razak Research Center) - United Kingdom, a research institute specialized in technologies for the use of rubber in seismic devices;
- Bombardieri SpA - Italy: a company with several decades experience in the design and manufacturing of equipments for laboratory testing.

As far as the project management is concerned, with DICA being the responsible for the overall scientific coordination and thus in charge of ensuring that the specific technical and scientific targets of the project are duly met, Numeria, in addition to technical activities, plays the roles of operations support to the coordinator.

2.4 Expected results

The project main expected outcome will comprise:
- technological transfer, through the training of technicians, the preparation of technical reports and the definition of a laboratory layout;
- input for the development of an Algerian standard for the testing of SI devices and for the design of SI buildings, through the drafting of guidelines;
- demonstration activity, through the application of the research developments into a real case study;
- knowledge dissemination, through the organisation of either high technical level and introductory workshops;
- improvement of bi-lateral scientific and technical relations, through the development of joint research and design activities;
- R&D impact, through the inclusion of Algerian researchers in international SI research community;
- social impact, through the education of Algerian experts in the use of SI systems;
- economic impact, through the reduction of seismic vulnerability by means of a proper application of the "integral seismic protection" philosophy concepts.

3 PROJECT FIRST YEAR ACHIEVEMENTS

Activities started in April 2007, further to the formal approval of the project, and concentrated, according to the working program, on the definition of performance needs, the data collection and the identification of the most suitable SI systems. Work proceeded as planned with no major deviations; particular attention was devoted to the R&D and socio-economic aspects.

3.1 Deliverables

A set of deliverables has been produced by the partners. By making reference to abovementioned work packages; the Tables 1, 2 and 3 hereinafter reported summarise the material produced so far.

Table 1 Work Package 1: problem definition and data collection

Objective	Deliverable
Analysis of Algerian typical structural configurations, materials and construction technologies for new and existing structures	Technical report on typical structural configuration (hardcopy)
Definition of the performance needs and selection of the most effective SI systems	Technical report on the selected systems (hardcopy)
Software evaluation	Technical report on software performance evaluation (hardcopy)
Introductory workshops	Workshop held in Algiers on May 2007

Table 2 Work Package 2: design procedures definition, demonstration activities & contribution to the standard

Objective	Deliverable
Material and components specifications for the manufacturing of SI devices	Technical report (hardcopy)
Drafting of guidelines	Technical report on guidelines content (hardcopy)
Implementation of demonstration activities	Pilot application selected – design in progress
Technical workshops	Definition of workshop programme; 1st technical workshop held in Algiers in August 2008 Production of training material

Table 3 Work Package 3: technological aspects

Objective	Deliverable
Definition of relevant acceptance and qualification tests	Technical report on testing procedures and experimental set-up definition (hardcopy)

3.2 Training and workshops

Training activities comprised two main lines of action: production of training material and organisation of workshops, as described below.
As far as the production of training material is concerned, besides the technical reports illustrating the results achieved (Figure 1) and the recommended specifications, training material reports have been produced and edited with an aim of not only serving as a means of results dissemination but also actually becoming valid and effective training and guidance tools, to be used by relevant professionals.

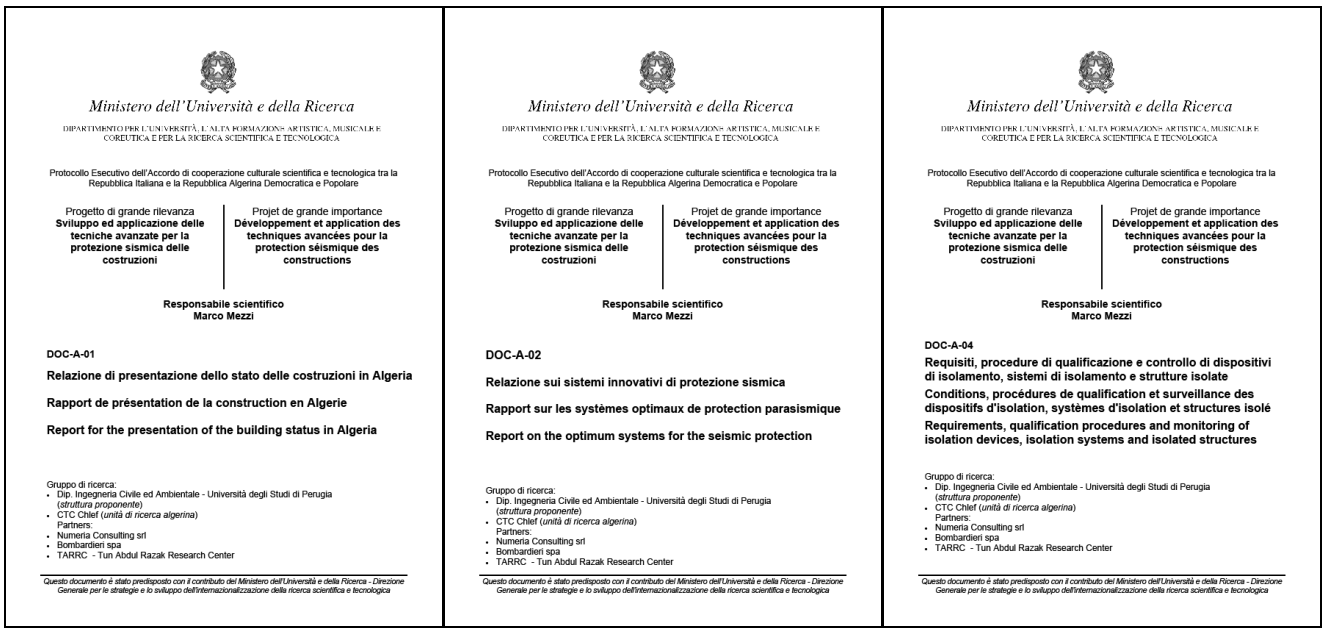

Figure 1 Some of the printed reports prepared during the activities of the first year

Within the scope of engaging with an audience that goes beyond the research community (i.e. governmental organizations, potential private end-users, mass-media, the public as whole, etc.), an introductory workshop, with the participation of more than one hundred attendees, has been held in Algiers on June 9-10, 2007.

4 PROJECT SECOND YEAR DEVELOPMENT

4.1 Knowledge dissemination and training

The planned technical dissemination and training activity will be practically accomplished by means of the organisation of three workshops, each one having a duration of three days.
A first training workshop, dedicated to a selected group of Algerians technicians and engineers for transferring a structural dynamic and seismic engineering background, has been organised in Algeria in August 2008. Aspects covered in the aforesaid training session are briefly resumed in Figure 2.

1. PRINCIPLES OF SEISMOLOGY

2. EARTHQUAKE AND STRUCTURES
Intensity scale. Ground motion recording. Characteristic parameters of the seismic motion. PGA. Response spectrum. Site effect. Damage from earthquake attacks.

3. DYNAMICS OF STRUCTURES
SDOF systems. MDOF systems. Non linear response. Vibration isolation.

4. CONVENTIONAL PRINCIPLES OF EARTHQUAKE RESISTANCE
Force. stiffness. Ductility. Regularity. Redundancy. Tenacity. Configurations

5. INTRODUCTION TO THE NEW SEISMIC PROTECTION TECHNIQUES
Base isolation. Energy dissipation. Active/hybrid control.

6. PRINCIPLES OF BASE ISOLATION
Frequency shift. Additional damping.

Figure 2 Contents of the training workshops held in August 2008

4.2 Demonstration project

The application of the research developments into a real case study has been successfully started and a pilot application of base isolation technology has been identified in the first semester of 2008. The building chosen is to be the new headquarters of the Daïra in Ain Defla, a town located in northern Algeria in a high seismicity area. The building, due to its strategic importance and to the role that the Daïra will play in the post earthquake emergency phase, is required to be fully operational during and after an earthquake.
As there is not yet an Algerian code for base isolated structures, approaches based on various international guidelines have been evaluated by the team. Research activities carried out in the framework of the bilateral project led to the final choice of the Italian guidelines as reference code for the structural analyses and design.
The building consists of five storeys above ground and one below ground. Figures 3 and 4 show the main façade and a cross section, respectively.

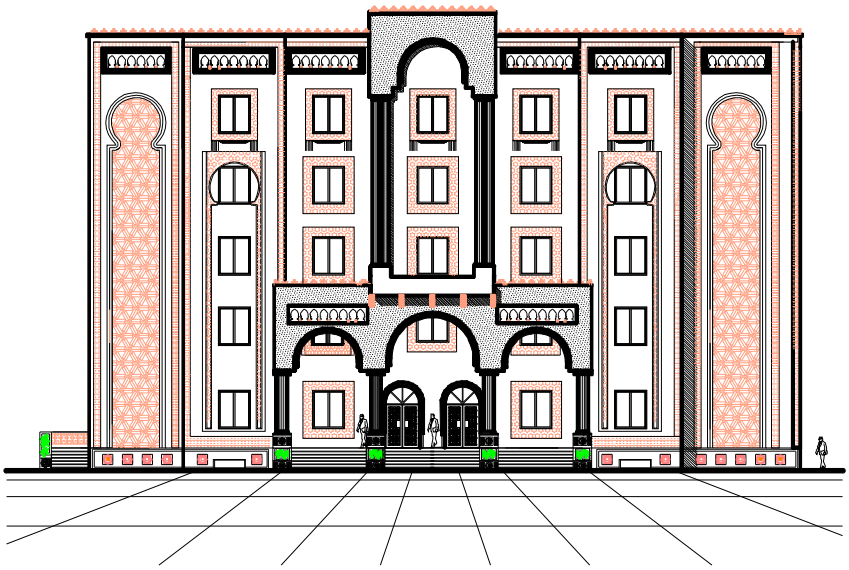

Figure 3 Daïra main façade

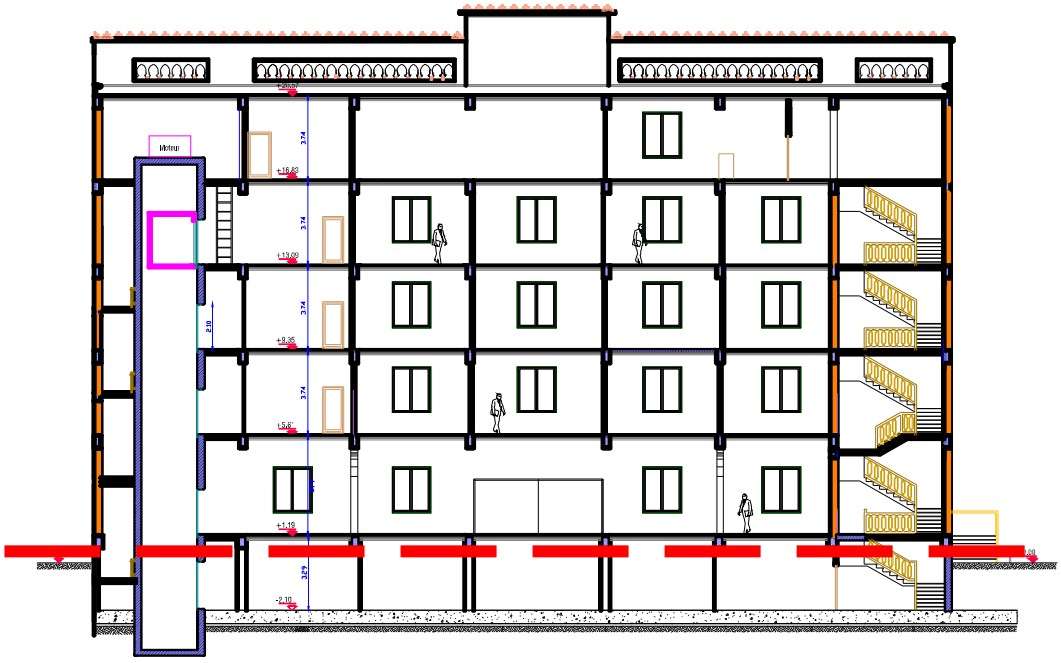

Figure 4 Daïra cross section with the location of the isolating level

From the structural point of view, the building is, in its base isolated configuration, a reinforced concrete framed (r/c) building, with non-structural infill and boundary r/c walls at the basement. It is worthwhile mentioning that, according to the current Algerian seismic code, should the building being constructed according to a conventional approach, extensive use of shear wall must be made.

Taking into account that this is a demonstration project, the design of the structure and the isolation system call for the need of detailed analyses and studies, partly still in progress. For the sake of comparison, conventional design, based on the Algerian code for the seismic design of structures, and the base isolated solution have been compared.

A series of analyses has been carried out in order to find the optimal configuration of the isolation system, considering a target isolation period of 2.5 sec. A dual isolation system has been used, consisting of High Damping Rubber Bearings (HDRB) coupled with low-friction Sliding Devices (SD). The isolating devices are to be installed at the top of the basement columns and perimeter walls. Bearing types and locations were chosen

so as to have a good coincidence of the centre of mass of the structure (projected on to the isolation plane) with the centre of stiffness of the isolation system.
Ground work preparation started in June 2008 and construction of the building is expected to finish in 2009.

4.3 Technology spreading

As a first practical outcome of the dissemination activity carried out so far in the bilateral research project, it is worthwhile mentioning the interest shown by the Algerian local authorities in the application of the base isolation technique to a new hospital to be built in the Wilaya of Ain Defla.
The hospital (Figure 5), capable of hosting 250 patients and deemed to serve one of the most populated high seismicity area in the north-western part of Algeria, was initially designed as a conventional structure. More recently, as per decision taken by the local Governor and the relevant administrative organisations, the hospital design is being fully reviewed, according to the base isolation concepts, by a team of Italian and Algerian technicians, working under the coordination of the project partners.

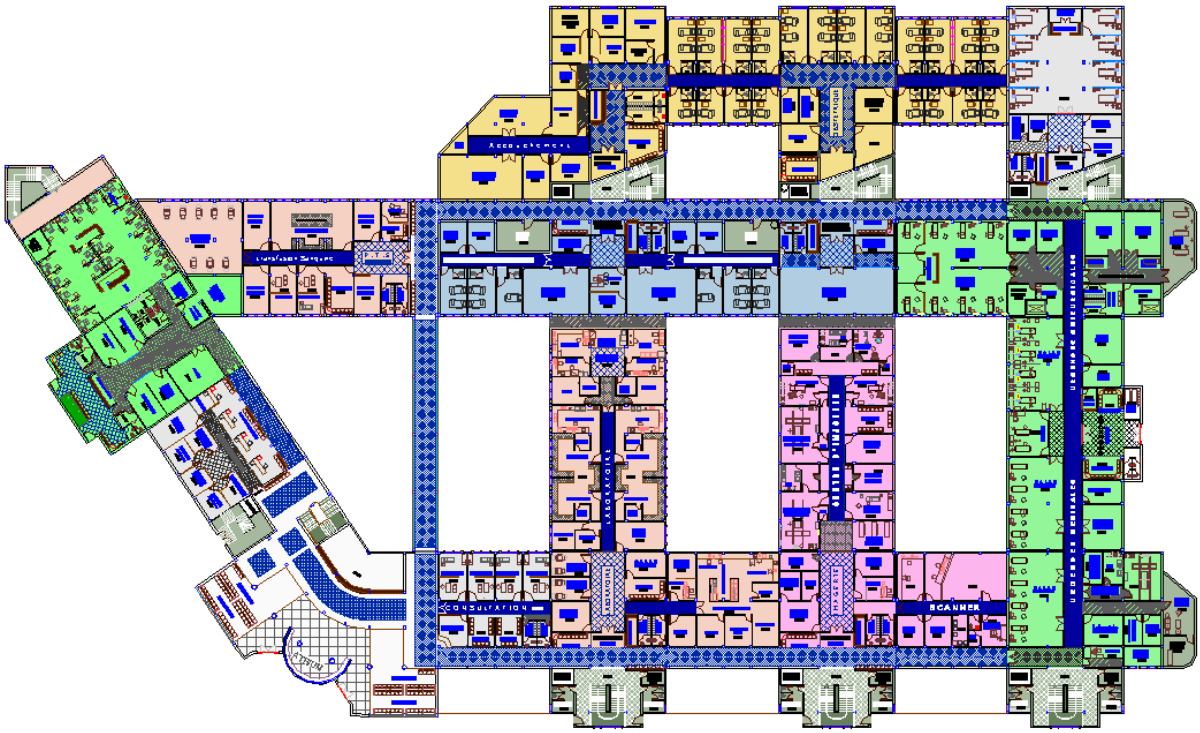

Figure 5 Ain Defla new hospital typical floor layout

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of *Ministero dell'Università e della Ricerca - Direzione Generale per le strategie e lo sviluppo dell'internazionalizzazione della ricerca scientifica e tecnologica.* We would also like Confortal S.p.A. for its assistance, helpful discussion and support in the design of the demonstration project.