MECHANICAL ENGINEERING L PHYSICS I PRESERVATION OF THE ARCHITECTURAL HERITAGE I SPATIAL PLANNING AND URBAN DEVELOPMENT I STRUCTURAL SEISMIC AND GEOTECHNICAL ENGINEERING I TECHNOLOGY AND DESIGN FOR ENVIRONMENT AND BUILDING I TERRITORIAL DESIGN AND GOVERNMENT I URBAN PLANNING. DESIGN AND POLICY I AEROSPACE ENGINEERING I ARCHITECTURAL AND URBAN DESIGN I ARCHITECTURAL COMPOSITION I ARCHITECTURE. BUILT ENVIRONMENT AND CONSTRUCTION ENGINEERING I ARCHITECTURE, URBAN DESIGN, CONSERVATION OF HOUSING AND LANDSCAPE I BIOENGINEERING I DESIGN I ELECTRICAL ENGINEERING I ENERGY AND NUCLEAR SCIENCE AND TECHNOLOGY I ENVIRONMENTAL AND INFRASTRUCTURE ENGINEERING **IINDUSTRIAL CHEMISTRY AND CHEMICAL** ENGINEERING I INFORMATION TECHNOLOGY I INTERIOR ARCHITECTURE AND DESIGN I MANAGEMENT ENGINEERING I MATERIALS ENGINEERING I MATHEMATICAL MODELS AND METHODS IN ENGINEERING

PhD Yearbook | 2017



Chair: **Prof. Enrico De Angelis**

Vision

We are a new (2012) *Doctoral Program*, evolution of five other programs, active since the institution of the Italian Dottorato di Ricerca (PhD) in 1988, that merged to create a national reference point for training researchers and experts in *Architecture, Built Environment* and *Construction Engineering*. Our working field includes any critical subject or question related to:

- the sustainable transformation and management of the *Built Environment*, holistically viewed as an environmental, economic, cultural and social ecosystem, as well as time and space series of *Architectures* and cultural landscapes;
- the *Engineering* of buildings and components, structures and infrastructures, materials and service systems those architectures and landscapes are part of;
- the organization of the *Industrial System* that design, realize, manage and transform them and the *Public Administration System* that defines the rules for taking care of their value as social assets.

Program organization

The Program pursues the following ten pillars:

DOCTORAL PROGRAM

BUILT ENVIRONMENT AND

CONSTRUCTION ENGINEERING

IN ARCHITECTURE.

- 1. *Selection* through a full transparent, efficient and supportive open process.
- 2. Candidates as independent, mentored and monitored, *early stage researchers*.
- 3. Training plans *tailored* on Candidate's research topic, needs and potentials.
- 4. Training activities based on research practice.
- 5. Research practice hinged on the framework of Department activities.
- 6. Transparent tracking of Candidates' scientific production.
- 7. *Systematic assessment* and open peer review of Candidates' advancements.
- 8. Candidates as *nodes* of *networks* of researchers and research institutions.
- 9. Systematic valorization of PhD holders and their products among stakeholders.
- 10. Candidates as active part of the Program's Quality Management System.

The award of ABC-PhD title requires that Candidates, under the control of their Supervisors:

- plan and carry out a *three year*, *full* time, research activity;
- plan, attend and pass, with positive evaluation, a complementary series of *Doctoral Courses*, to complete her/his skills as researcher.
- develop a *PhD thesis* and defend it, in a *Final Exam* session certifying its original advancements on a specific *topic*.

For what concerns *courseware*, ABC-PhD Program boasts a wide (more than 20 titles/yr), diverse, educational assortment on cutting edge, specialized, research topics. It is an open list of courses that changes, year after year, following Candidates' needs as well as the opportunities offered by the Department. This list is further enriched with the *transferrable skills* courses offered by the PhD School and may be integrated by the offer of all the Politecnico Doctoral Programs.

Academic, industrial and social collaborations

Each Candidate is mentored by one main Supervisor and inherits Supervisor's Scientific Sector as reference. Due to the multidisciplinary nature of our wide research field, nevertheless, his/her activity may be supported by other co-Supervisors to make stronger, more sound and reliable his/her final research product. The main effort of the *Board of Professors* is to keep Candidates research works constantly reviewed, involving every useful, available competency from the ABC Department, other Departments or other national and international Universities and Research Centers.

Moreover, each Candidate is progressively encouraged to confront his/ her position, project, intermediate products and final results with any stakeholder that may acknowledge, enhance, valorize and exploit them through social or industrial collaborations. Our social and industrial collaboration starts often from the beginning: approximately 50% are thematic and the topic is defined (and the Candidate selected) together with an industry or an international research institution as funding – or co-funding – partner.

PHD BOARD OF PROFESSORS		
Enrico De Angelis (ICAR/10),	Carlo Castiglioni (ICAR/09)	Gabriele Masera (ICAR/11)
Head of the Board	Andrea Ciaramella (ICAR/12)	Gabriele Milani (ICAR/08)
	Angelo Ciribini (ICAR/11)	Elena Mussinelli (ICAR/12)
Niccolò Aste (ING-IND/11)	Giuliano Dall'O' (ING-IND/11)	Cristina Pallini (ICAR/14)
Luigi Biolzi (ICAR/09)	Bruno Daniotti (ICAR/11)	Maria A. Parisi (ICAR/08)
Raffaella Brumana (ICAR/06)	Adalberto Del Bo (ICAR/14)	Tiziana Poli (ICAR/10)
Andrea Campioli (ICAR/12)	Daniele Fanzini (ICAR/12)	Sara Protasoni (ICAR/15)
Roberta Capello (SECS-P/06)	Massimo Ferrari (ICAR/14)	Lionella Scazzosi (ICAR/19)
Stefano Capolongo (MED/42)	Carmelo Gentile (ICAR/09)	Cinzia Talamo (ICAR/12)
Siro Casolo (ICAR/08)	Mariacristina Loi (ICAR/18)	Angelo Torricelli (ICAR/14

Our mission is to train our PhD Candidates as self-sufficient and independent actors, able to gain – as scientist, as intellectuals, as professionals, as entrepreneurs – an outstanding position at an international level.

64

We are sure that our early stage openness toward stakeholders and the whole scientific world and networks is the best way to provide future PhD Holders with solid occupational opportunities for an academic career as well as for an employment in research centres and in any other enterprise, public body or private societies in need of highly qualified personnel, in particular of experts trained to innovate and to manage innovation processes.

HEAT ISLAND MITIGATION STRATEGIES, WITH FOCUS ON THE URBAN SHADING DEVICES. THE CASE STUDY OF ABU DHABI MAIN ISLAND, UNITED ARAB EMIRATES

Bande Lindita - Supervisors: Prof. Paola Ronca

The aim of this PhD thesis is to propose mitigation strategies for the Urban Heat Island (UHI) in the cities of the hot arid countries. UHI, i.e. higher values of air temperature and relative humidity in urban areas, compared to rural areas, is an increasing phenomenon that brings out a great challenge in urban planning and in the design of the transformation of cities like Abu Dhabi, whose recent growth has not taken this phenomenon into consideration.

The proposed UHI mitigation strategy are the Outdoor Shading, the Vegetation and the Cool surfaces, aimed both at improving outdoor thermal comfort and the reduction of building cooling load. A combination of the three of them is proposed, for the case study, to be applied on mid/highrise buildings districts and villas districts.

In order to propose any UHI mitigation strategy on a case study, a complete understanding of the city structure and its past and future development is fundamental. The first part of the thesis gives an overview of Abu Dhabi historical city, its expansion, the current problematic zones and the new areas that are expanding toward the desert. Compared to ancient Islamic cities in the region (characterized of narrow streets and arcades), the new districts of Abu Dhabi have large streets and in most of the areas, the streets are under the sun full day.

The core of this research is the modeling of two Abu Dhabi districts. A CFD software has been used to predict outdoor conditions (temperature, wind speed, relative humidity etc.) based on different scenarios. The obtained results has been evaluated in terms of Physiological Equivalent Temperature (PET) and Building Cooling Load (at a district level). The impact of a mitigation strategy have been assessed in term of cooling load reduction for the district buildings and in terms of modification of the average PET 24h profile.

The results confirm a high impact of mitigation strategies. The peak PET, for example, may drop up to 4 degrees, with shading devices, in spring, in the summer, in the same district the PET gets reduced by 5 °C. If mitigation strategies were extended to all the districts in Abu Dhabi, the microclimate might be improved much more. The analized shading devices and their distribution is based on the canyon physical characteristics in each district. The geometry of the district, the height of the buildings, the width of the

streets within the neighborhoods make shading device application feasible or not. Green shading devices are also evaluated. The leaves canopy produces shadow absorbing the shortwave radiation, don't increase the cooling loads and, if properly chosen, the plants do not need excessive amount of irrigation water (a calculation is proposed in the annex section) and may climb supporting structures realizing a wider shading in the streets of the urban canyon. The drop of the average air temperature is lower, about 0.5-0.8 degrees, but this may reduce cooling loads up to 13%. The modification of the internal air temperature set points might bring to further and higher cooling load reduction, and still

improved if additional retrofit strategies are applied like external shading devices placed at a 5-7 meter height in the villas district (average height of the two floor villas is 8 meters).

In order to validate UHI mitigation strategies, site measurements too are fundamentals, in particular to make the CFD models needed to predict their results more reliable. A net of sensors in a three year survey have produced data to validate the different softwares used in this research (in particular ENVI-met and UWG – Urban Weather Generator). An even wider network of weather stations and other sensors will be installed in a larger district scale after this first approach.

SIMPLE COMPATIBLE HOMOGENISATION STRATEGIES. APPLICATION TO UNREINFORCED AND FRCM REINFORCED MASONRY STRUCTURES IN AND OUT OF PLANE LOADED

Bertolesi Elisa - Supervisors: Prof. Gabriele Milani, Prof. Carlo Poggi

Masonry is a composite material constituted by bricks (or blocks) joined by mortar. The variability of the masonry bond (or arrangement of the bricks), the shape and dimension of the bricks, as well as the guasi-fragile behaviour of the constituent materials, make the analysis of masonry still a challenging task. In the last thirty years the qualitative understanding of the masonry, reinforced and unreinforced, mechanical behaviour has grown thanks to the contribution of experimental and numerical research. At present, two types of numerical approaches are widely used in the literature for masonry modelling: they are called in the specialized literature as micro- and macromodelling. Micro-modelling is considered the most accurate technique for the simulation of heterogeneous inelastic media, because bricks and mortar joints are modelled separately. On the other side, macro-modelling doesn't make any distinction between units and mortar joints and uses equivalent homogeneous mechanical properties to describe masonry behaviour. A compromise between the aforementioned two approaches is represented by homogenisation. Homogenisation

consists in extracting a

Representative Element of Volume (REV) that generates the whole structure by repetition, in solving a boundary value problem on the REV and in substituting the assemblage of bricks and mortar at a structural level with a fictitious orthotropic equivalent material.

In the present thesis, two slightly different simplified homogenisation two-step procedures are proposed for the analysis of masonry structures in and out of plane loaded. The first (Model I) translates the mechanical problem into mathematics by means of a small scale system of non-linear equations, which is solved with standard general purpose algorithms. The second (Model II) is a semi-analytical two variables procedure. In both models, the unit cell is meshed by means of 24 triangular constant stress (CST) plane stress elements (bricks) and linear interfaces for mortar joints. Triangular elements are assumed linear elastic, whereas the mechanical response of the interface elements is modelled by means of different holonomic laws including two dominant failure modes, namely cracking (mode I) and shear (mode II) or a combination of two (mixed mode). Such cohesive relationships are characterized by a post-peak

softening branch, with possible coupling between normal and shear relationships. The structural analyses are performed via the implementation of the homogenised stress-strain relationships into a FE code dealing with softening materials using a rigid element approach (RBSM) where contiguous rigid elements are connected by shear and normal non-linear homogenised springs. In the thesis, it has been labelled has HRBSM to stress the meso-scale homogenisation step. The main advantage of such procedure is that meso- and macro-scale are fully decoupled, while the disadvantage is the intrinsic mesh dependence of the results in case of global softening. The outcomes provided by the homogenisation are benchmarked in the elastic field, considering several closed form expressions available in literature and then, using FEs. To this scope, the mechanical properties of both bricks and mortar joints are assumed varying in a range of technical applicability. The models are then extended to the non linear field assuming two different holonomic laws for the description of the normal and tangential responses of the inelastic interfaces. To evaluate the results provided by the

proposed approaches, two masonry running bond textures are considered namely a stretcher bond and header bond patterns. At structural level, a variety of different problems, for which experimental and numerical data are available in the literature, are considered. The models (Model I and Model II) demonstrated to accurately capture the global behaviour of in plane loaded masonry structures as well as to suitable describe the failure mechanisms with a limited computational effort. An extension of the procedure is proposed to deals with the application of FRCM reinforcements on a masonry wall tested in diagonal compression. The masonry panel, for which extensive experimental data are available from the literature, is modelled using the simplified homogenisation procedure and a sophisticated 3D micro modelling heterogeneous approach. The reinforcement, which is

constituted by two distinct materials, is simulated by means of two numerical strategies with increasing level of accuracy. The two step homogenisation procedure is then extended to out of plane loaded masonry structures by a simple on thickness integration. In this framework, the momentcurvature relationships are evaluated starting from the homogenised stress-strain curves. The RBSM model is then modified, to allow the description of flexure behaviours, horizontal and vertical, as well as torsion. Similarly to the in plane case, the identification of the mechanical parameters is performed via an energetic equivalence. The proposed out of plane approach is benchmarked studying some panels under two ways bending, for which experimental data are available in literature. In order to evaluate the capability of the proposed model for the analyses of different out of plane failure mechanisms, several masonry panels characterized by different geometries, boundary conditions as well as various pre-compression loads are considered. In all cases, a satisfactory agreement between the experimental and numerical results is found. The last part of the thesis is focured on the ceismic applysic

focused on the seismic analysis of masonry building subjected to earthquakes using the proposed homogenisation model. In particular, a church façade modelled with a portion of the perpendicular walls and a tridimensional building prototype are studied under non linear dynamic excitations by means of the proposed homogenisation model. Very good agreement is found between present results and existing literature data (both experimental and numerical) meaning that the procedure discussed in the thesis may be of practical interest in the non-linear dynamic range.

CONSTRUCTION SITE INFORMATION MODELING. IMPLEMENTING BUILDING, CONTEXT AND OPERATIONAL INFORMATION TO MANAGE **CONSTRUCTION SITE DESIGN**

Cassano Manuele - Supervisor: Prof. Marco Lorenzo Trani

Construction sites are strictly related to the satisfaction of every main need of the project they realize (quality, expected time and cost compliance for what concerns client's side): moreover, their management, productivity and health and safety conditions strongly influence their sustainability for every other stakeholder, from an environmental, economic and social point of view. It is known, however, that sites are frequently affected by complications, sometimes due to a scarce attention on operational issues during design phase. In fact, construction site planning is often taken into consideration in an advanced stage of the project, in which most of the design choices are already defined. It is quite usual to transfer the responsibility of the main construction choices, especially in small works, directly to the Contractor without any review from them before the close of the design phase. The planning of construction site activities since the early design phases has, instead, a great impact on the success of the subsequent execution phase particularly in terms of time and cost saving as well as of workers' safety, especially if faced at the appropriate time.

70

Starting from this background,

the research aims to create a strong conceptual framework able to characterize the main steps of a construction planning development during the different phases of a building project. Such a framework needs to be based on a complete set of data about each part of the project as well as the works and the resources needed to be realized. Concerning information management, we are seeing nowadays a revolution in the construction industry. The continuous development of Information Technology tools allows us to manage in a quicker and simpler way the great quantity of data related to the built environment. For this reason, the research starts from the analysis of the construction site -planning process, to identify all the information needed by the process itself and its digitalization opportunity. Nowadays Building Information Modelling (BIM) is certainly the most popular method for enhancing informative and collaborative design. Its quick diffusion and its well-known advantages obviously make it a

powerful tool also for construction site design, since the possibility to share design information in a simply readable format like

the 3D visualization. Then, the possibilities to collect operational information on a unique platform and to share them with the whole design team could move site designer closer to his colleagues of the other disciplines. Nevertheless, a shortage of BIM tools specifically studied for construction site design is still detectable among BIM software. The few tools specifically oriented towards construction takes in account more on-field management rather than the planning of construction activities. For this reason, another aim of this research is to develop a precise workflow able to integrate site design in a BIM design process, gaining operational advantages from BIM technique. Additional task of this research is the development of specific tools that permit to apply the studied workflow and to obtain, as a result, a proper Construction Site Information Model (CoSIM). CoSIM is intended both as the model able to represent each aspect of the construction site both as the method able to realize this model (as well as BIM is). The realization of the stated objectives starts from a wide literary and on field research about construction planning standards and practices.

The stated problems was in



fact confirmed by an on-field observation, carried on during direct experiences, and further confirmed by construction stakeholders' interviews and literary research The review implies also a deep technical data analysis useful for the development of the construction models. In fact, they need to be populated by the information needed to take decisions about construction works organization and management, from the first design stages. For this reason, the research first identified the information need for construction site planning. The management of such information permits to realize the steps of the workflow for the proposed process of construction planning realization in practice. Furthermore their expression in a standardized way permits a simpler and quicker management. The amount of founded and expressed information can be then described as the requirements for the

1. Example of a Construction Site Information model.

Model

realization of a CoSIM.

In fact, once defined the

information needed to describe

construction elements in terms of

construction site planning, it was

possible to build the framework

of Construction Site Information

Modelling, i.e. to translate such

information in a BIM environment.

This meant modelling a library of

construction elements coupling

CoSIM information, in a different

LOD scale (specifically defined for

construction elements), together

with all the other graphic details

The development of the libraries

is funded on the concept of data

interoperability. For this reason,

information standardizations and

modelling issues are focused on

the possibility of implementing

them in the IFC schema.

The elements of the library

defined the main contents,

in terms of information, of a

Construction Site Information

Model. In addition to this, the

presented research developed

and experimented other methods

and information contents.

To reach this goal, project templates were created and successfully tested, in order to facilitate modelling and to automatically check project data. The developed methods and the related tools were applied in case studies, in order to evaluate their effectiveness. A further evaluation was given by additional interviews to professionals involved in site design. As a result, the proposed approach and the related tools permitted to improve and facilitate construction-planning reducing in particular design time. A comparison with traditional design showed, in addition, more precision in workspaces design and in construction time and costs calculation. Visualization issues were also very appreciated during operational procedures, especially for what concerns health and safety planning and management in complex situations. Finally, the sample of interviews responded positively about the developed approach giving awareness about its utility on field.

main aspects have been studied. regarding both simplicity of modelling and planning efficiency. The first aspect concerns the efficiency improvement of site modelling activity (site design aspects). The second aspect concerns, instead, the review of design choices for what concerns construction site planning, thanks to a semi-automated management of the panel of information contained in each

of a CoSIM during all design phases. To reach this goal, two PhD Yearbook | 2017

FOR THE RELAUNCH OF THE PUBLIC INITIATIVE. GOVERNANCE MODELS AND FINANCING TOOLS FOR URBAN REGENERATION PROCESSES

Castaldo Giovanni - Supervisor: Prof. Fabrizio Schiaffonati

The research addresses the issue of urban regeneration projects of large-sized brownfields, focusing on process governance and their economic feasibility. The general objective of the thesis is to identify the most appropriate spatial solutions, procedural models and financing instruments to ensure the viability of the project and its optimization for the public good, under the control of local authorities. The research question mainly arises from a critical reading of projects of urban transformation realized in the Italian context in the last decades. Recent studies, in fact, have shown that the majority of projects of redevelopment produced an imbalance between the private and the public return, the first in terms of additional profit beyond the return on the investment, the second in terms of underestimation of the extent of public assets and facilities financed through the real estate operations. Indeed, the public sector often stands in a weak position both in terms of decision-making (e.g. lack of strategic vision and multi-scalar structural planning tools) and for what concerns the economic and financial strength (e.g. low taxation on real estate operations and budget constraints). The weakness of this approach to the modification of

cities and financing public goods has been further exacerbated by the financial crisis, with increasing difficulties in activating initiatives of transformation even by private investors, opening up to the necessity to introduce new models of governance and financing the construction of the public city. Within this general framework of issues and objectives, the output of the research consists in the formulation of guidelines for local public authorities, regarding the management of regeneration processes.

The research assumes the technological design as a search tool, as a mean by which to study a problem and offer solutions. Thus, from a methodological point of view, beyond a theoretical research referring to the state of the art in the fields of urban regeneration, urban finance, public-private partnerships and governance models, this thesis develops a design-oriented stream of research.

In accordance with the abovementioned objectives and methodological assumptions, the work is structured into two main parts – one more theoretical and one designoriented – and more precisely into six chapters, including the conclusions with the output of the research. The first chapter deals with the issue of public-private negotiation, investigating how the transformation of large-sized brownfields has been faced for the last twenty years in particular within the context of Milan. Through an analysis based on the theoretical basis of urban finance, it emerges a non-optimal allocation of the capital gain between public and private parties, with specific criticalities regarding the quantity and quality of the public benefit (e.g. average publicprivate convenience indicator -Rccp < 40 %). The original results of the analysis applied on the case of Milan are coherent with studies conducted by other researchers and scholars in the field of urban finance and urban development. In the second chapter, the overall set of instruments for the financing public assets is investigated, with a particular reference to the framework of the public-private partnership tools, beyond the negotiation practice. The most advanced forms of cooperation between public and private parties and citizenry are studied as well, deepening regulation framework, theoretical basis and fields of application of each tool. Since the construction of the public city is conceived not only as a matter relating to its financing, but also as an issue related to the management of the process

of urban development, the third chapter involves a detailed analysis of a specific case study: the project of regeneration of the Central District of Rotterdam. This case study, which well describes a multi-stakeholder and multilevel approach, has been directly analysed on the field, during the visiting period at the University of Technology of Delft (TU Delft), with also the opportunity to conduct an interview with one of the main actor of the project. Findings and conclusions from this case study are outlined, with particular reference to the notion of complexity-based governance framework. From the fourth chapter the design-oriented phase begins. In particular the fourth chapter is devoted to the identification of an appropriate test site within the context of the metropolitan area of the city of Milan; a brownfield where conducting the design experimentation characterized by the research of innovative design, procedural and financing solutions oriented to maximize the public return. Through dimensional and localization analysis of brownfields at the metropolitan scale, the segment of dismissed railway yards is recognized as a privileged field of experimentation. The analysis is conducted through the improvement of existing databases

referring to brownfields and the adoption of specific indicators (e.g. indexes of concentration). Moreover, the use of a software (GeoDa) for graphically representing the results supports the analysis. Among the dismissed railway yards a qualitative analysis structured on the base of six indicators, shows the railway yard of Porta Romana as proper site for the design experimentation. The fifth chapter concerns a design-oriented phase conducted on the test site, defining and detailing two different scenarios of regeneration. The two scenarios reflect two approaches to the transformation of the area. both oriented to maximize the public return. The first scenario is based on an improvement of the negotiation-based approach, within a private sector oriented perspective of redevelopment, focussing on a more equitable allocation of the capital gain, on the definition of a governance model based on the notion of life-cycle thinking as well as on the original characterization of the indicator Rccp. Then, an economic analysis of the hypothesis is conducted in order to demonstrate its feasibility. On the other hand, a more public sector oriented approach is investigated, through the definition of a scenario based on a central role played by the

local public administration in the activation and the management of a complexity-based governance framework. The application of innovative tools of partnership between public sector, private sector and citizenships as well as of models of cooperation is envisaged and verified through economic analysis. More in detail, real experimentations conducted directly on the field during the research activity, involving local authorities, associations and local private stakeholders in bottomup initiatives of cooperation and financing of public and common goods are descripted and analysed. Finally, the sixth chapter reports the conclusions, extrapolating guidelines for public administration in order to outline operational models, to be applied in similar situations to the Porta Romana test site. This chapter specifies the terms for transferability and scalability of the guidelines, as well as the definition of possible further research developments.

WHAT SPACES FOR WHAT COMPANIES? STRATEGIES AND RE-USE OF IDLE AND ABANDONED AREAS

Celani Alberto - Supervisor : Prof. Gianandrea Ciaramella

The scope of this investigation work is determined by the availability of brownfield areas with industrial origin and the potential demand for space from investors and the need to identify new sites for production or for the expansion of existing headquarters.

The research is organized in four parts. The first part is devoted to the analysis of the land supply in a selected pilot regional area in Lombardia, in terms of idle and abandoned industrial areas. studying the potential of the supply in terms of availability. The second part is focused on the analysis of the demand, i.e. the identification of the potential needs of the industry; potential investors have been defined as companies aimed to locate their business in the areas identified as available in the first part. An original method to assess the needs of the companies, when to locate their business in a new area, has been developed for this work. The method is adapted from needs analysis performed in Total Quality Management for manufacturing industry. The third part is a benchmark analysis of the offer of the Investments Promotion Agencies (IPAs) for studying the potential of the territory in relation to Foreign Direct Investments (FDI) attraction. This part has

been performed in order to define a strategy for defining a supplement for the internal demand, not consistent due to exogenous factors such as the global crisis. The idea of attraction and retention of firms is delivered in this phase. The fourth part is the project for the valorisation of idle and abandoned industrial areas for production, and the Foreign Direct Investments (FDI) attraction strategy in the Pilot area. The purpose this work can serve is twofold: it develops a promotion strategy for territorial areas for attracting Foreign Direct Investments with a special focus on the investments aimed into brownfield regeneration and defines a rational use of land, considering new functions like spaces for modern manufacturing in urban areas.

To identify the needs of location of a company it has been chosen to review and adapt methods derived from Quality Management in Manufacturing Industry, and to determine the opportunity, for a company to change the place for its activities on the basis of the externalities, the territorial aspects and their advantages in relation to Urban Regeneration policies, from a wide point of view, thinking business location as a strategic choice.

The context of this work is the

actual availability of brownfield areas with industrial origin, the potential demand for space from investors, their need to understand the advantages for a relocation and to properly identify the best areas for them, either to answer an expansion need, a change of layout or a change of venue.

The needs analysis should enable the overcoming of what it is currently called "Territorial Marketing" as the only mean of promotion and attraction of investments in the production sector, or to make it more effective relating it to the potential demand and not only on what the area may offer in terms of advantages for the investor indistinct. Moreover, also the nodes of the process are analysed, the role of market transparency for business location on brownfield over the enhancement of brownfield sites. The national debate about urban regeneration and brownfields reuse is facing the issue of marginal re-functionalization of productive zones in terms of re-introduction of core businesses and promotion of the employment in abandoned industrial areas; nevertheless, a technical analysis of building requirements for which the potential demand is a carrier for the functional site recovery is often neglected. This lack lead, usually,

to choose to build new residential buildings, multifunctional cultural or social or commercial centres. The territorial integration component was analysed in foreign experiences in terms of attraction and retention strategies. Moreover, a focus on the authorization process and on land use planning practice aims to identify other nodes that accentuate the difficulty of the Italian system to bring the demand for land (that often comes fragmented, not properly defined or even unexpressed) from the Company closer to the supply of brownfield and abandoned areas or to promote their real "Activation" (i.e. making the area productive). It is difficult to have development policies matching with Regional data available. Much more difficult to have a real synergy and collaboration among the many public bodies competent in terms of business and land use management and regulation. This study aims, also, to integrate the approach defined by the observers on Public Administration performances (i.e. Oppal by Gesti.Tec lab, ABC department at Politecnico di Milano, Milano Chamber of Commerce and Assolombarda among others) about the identification of misalignments in the authorization processes with typological needs,

spatial and technical needs of the enterprises. On the operational side, it aims to provide integration of knowledge, policies and data with a more detailed focus and tailored on real estate studies of strategic (time axe) territorial (spatial axe) scale on the redevelopment of brownfields. The research investigates, also, the competition among the national Investment Promotion Agencies (IPA) in the global market of capitals for the attraction and retention of firms, a strategic goal for every Country, with Governments and Institution devoted to Economic Promotion often investing a huge amount of public money, in different and sometimes non-coordinated ways, over the same Country. The definition of an integrate strategy for attracting industrial companies is the goal of the measure proposed in the last chapter, that presents a benchmark analysis of the measure promoted by different agencies from the global scenario. The equilibrium between attraction and retention affects also the stock of brownfield in terms of vacancies: the internal demand if it is driven only by relocation strategies in terms of change of location derives in a potential creation of empty spaces

in the territory. For this reason,

the research has a focus on the strategies to attract and integrate new companies in the territory, as a support of the internal demand for spaces, weak and local. The research proposes in its final part an integrated project of territorial development, integrated with the multiple aspects of the issues of the thesis, complex and hidden into practices never explored in a deep way. This work adds a new vision over the idea of valorisation of territorial areas in terms of re-use of idle and abandoned industrial areas, a vision based on the equilibrium between the retention of companies already in the territory with the attraction of new companies from abroad, with new capitals and opportunities for the territory and for the industrial fabric of the Region.

Ferretti Marta - Supervisor: Prof. Matteo Gambaro

The research presented has defined a tool - named SQC - Social Housing Quality Control tool - for the techno-typological quality of social housing buildings and dwellings, to serve both as support and methodology to the design and as a base for the evaluation of the realizations.

76

The research starts from the awareness that the technotypological innovation is a key to undertake and achieve the goal of housing quality improvement from the point of view of the user (flexibility, size, furniture). The research field is multidisciplinary and multiscale and related to the history of housing and its design culture. It concerns the morphological, typological, technological, constructive and social aspects of the architectures, both at the scale of the building complex and at the scale of the house, one of the most investigated topic by XX Century architects. The research focus, through the reading of the paradigmatic case studies, on the analysis of the design process and the "good design" factors in terms of housing maintainability, usability, flexibility, durability.

The research also faces Italian legal and regulatory framework, the techno-typological constraints it generates and the feasibility of an innovative, low cost social housing meeting those quality needs. Finally, housing, at the dwelling and at the building scale is analysed in terms of users configuration and social aspects.

The research assumes a double value. On one side, it is a theoretical contribution about the basis of the assessment of social housing projects; on the other, it introduces a practical tool for the control of their quality. The theoretical contribution is based on the state of the art of housing: from the point of view of the Italian legislation and existing evaluation systems to assess construction quality. Selected case studies follow. their analysis (in terms of technotypological design, social, economic and management aspects) allowing to have a reference about the production of social housing in the last 10 years in Europe, in relation to countries that have a historical tradition in the field of social housing (Italy, France, England, Spain, Germany, Netherlands). Best design practices are defined, through the analysis of these case studies and, subsequently, outlined in a tool that has a dual function: to support and to assess the design choices, through the evaluation of the expected quality, based on the calculated value in use. The expected outputs of this

research work are mainly three. The first is a comparison between the virtuous experiences detected through the application of the developed tool. The second is related to the best practices extracted from the European cases and consists of a list of possible design solutions that may be considered excellent from a point of view of technotypological aspects at the dwelling and building scale. The third is represented by the supportassessing tool, organized as guidelines. The contents of the guidelines are all related to the phase of architectural design of the social housing building and dwelling and promote mainly the use of common and private living spaces. The requirements defined in the nineteen evaluation criteria have, where possible, both quantitative and qualitative value and take into account, in different weights, three indicators: architectural (environmental and dimensional quality), social (social inclusion, sense of community) and economic (containment of costs, maintainability). The tool was finally applied on four

Italian case studies as a necessary validation phase: to understand its limits and its possible evolutions. The critical and comparative reading following the quantitative and qualitative evaluations, seems to confirm the hypothesis that the more recent social housing projects suffer the effects of a kind of involution of the housing project in terms of quality fruition. Today the design attention tends - even as a result of mandatory regulations - to focus on the energy efficiency requirements, with consumption reduction targets, cost savings and containment of environmental impacts. And, on a different side, a lot of effort is spent looking for morphological and typological conformations that redeem social housing from the pauperism, homogenisation and degradation that in many cases have characterized the image. The fact remains that the newest building production, appears proof of a drop in planning capacity to verify even the most basic techno-typological parameters that guarantee the fruition quality of dwelling. The legislation redundancy, frequent incongruities and inconsistencies between

different devices, the burden of bureaucratic formalities seem to have lost sight of the ultimate goal of technical manuals, or energize a cogent and objective evaluation of the living space quality for the end user. Return to a control and addresses model of projects which operates by attaching to the architectural contest (social housing) the technical tools. with few but essential rules. could perhaps be an opportunity to envisage a new building production, realigned to adequate standards of building and dwelling's typological quality. Defining a support tool to the design / evaluation has had, from the outset, the overriding objective of improving the quality in the residential building field. This purpose can't be achieved without designing buildings and dwellings which take into account, at the same time, the high quality levels

from a technical and typological point of view, and a constant cost control. These two elements are added, today, even the social value of the interventions. This means it is no longer enough to provide low-cost housing. The research has shown that today's value gained from this type of housing policy mainly consists of the services offered, the ability to create a sense of community and belonging among users, in the type of social projects that manage to establish inside the new complex. Social experience is a driving force to other aspects such as the increase of passive safety in the new urban environment, the best maintenance of common areas managed by the tenants themselves and, in general, a more lively urban situation. No more dormitory communities like in the past years projects, still characterizing our cities, but new type of integrated cities.

TRANSFORMATION AS CONSERVATION. THE CITIES IN THE ISLAMIC WORLD AND HERITAGE INSTITUTIONS IN THE FIELD

Fumagalli Cecilia - Supervisor: Prof. Cristina Pallini

The research owes its title to the essay "Le città del mondo islamico tra conservazione e trasformazione" ["The cities of the Islamic world between conservation and transformation"], written by Paolo Cuneo wrote in 1982 for the catalogue of the Second Venice Biennale on the "Architecture in Islamic Countries" curated by Paolo Portoghesi. In his essay, Paolo Cuneo, for the first time, gathers a list of built and unbuilt architectural and urban projects carried out from the 1960s in several Islamic countries: restoration and conservation projects of historic buildings, rehabilitation plans for historic neighborhoods or entire cities, urban masterplans, emerge in the common ground of architectural and urban design strategies set up throughout the Islamic world, from Maghreb to India. The innovative character of the theory elaborated by Paolo Cuneo lies in understanding the city as a comprehensive phenomenon. In fact, while, in 1980, UNESCO held an International Symposium on Conservation and Restoration of Islamic Architectural Heritage bringing to the fore the sole architectural dimension of the urban phenomenon in the Islamic world, Paolo Cuneo introduced the issue of the conservation of

the cities of the Islamic world, in which he also includes the design of single buildings. The city became thus the focus to which the attention of researchers and professionals was directed and the platform where all the elements converged: it is no more the architectural heritage, but the urban heritage that matters. Moreover, Paolo Cuneo introduced the idea, somewhat revolutionary at that time, that conservation and transformation could be considered together as part of the same process. The research consists in the unfolding of this mechanism to demonstrate how the Islamic city is one of the major testing grounds for this approach. By doing so, the research aims to place itself in continuity with the Italian tradition of urban studies that, particularly at La Sapienza

found in the study of the historic cities of the Islamic world one of the most fertile, nevertheless disregarded by the Italian scientific community, field of exploration. While Paolo Cuneo considered conservation and transformation processes as two complementary approaches to the urban design within the historic cities of the Islamic world, the present research, based on these premises and on further achievements, aims to stress this complementarity by considering, within the framework of the city, transformation as a tool for conservation, breaking down the equivalence and the strict complementarity established by the Italian scholar in 1982. The historic city of the Islamic world is by its nature governed

in Rome and after Paolo Cuneo.



1. The five levels of the Islamic city (source: author)



2. Village in the vicinity of El Oued, Algeria, aerial photo (source: UNESCO)

by a 'self-regeneration process', according to which the persistent element of the city shall be found, at first sight paradoxically, in its continuous endogenous transformation over the time that does not alter, but rather confirms, its character. In this framework, the design process is the fundamental reference to assess, establish and evaluate the mechanisms of transformation. The urban project becomes thus the principal field of investigation, in order to verify and, consequently, to stress, the issue posed by the (no longer) binomial opposition between transformation and conservation. By investigating the relationship between the character of the Islamic city and the issues linked to its conservation and transformation as they have been posed by the international institutions operating in the field of the cultural heritage, the main goal of the research has been to understand the dynamics of transformation and conservation within the Islamic city. Moreover, taking into account the acknowledgment of



3. Bab al Sheikh Development Project, Ove Arup, Carlfried Mutschler Associates (source: Ove Arup)

the city - and no more the sole projects of their historic cores. architectural dimension - as the It is internationally claimed privileged fieldwork to understand that heritage is an important, the processes of transformation fundamental resource able to boost sustainable forms and conservation occurred in the Islamic world, and considered of development. Assuming the heritage as the global horizon the definition of 'sustainable where to inscribe the Islamic city development' as the in a no more local framework, "development that meets the the broader goal of the research needs of the present without compromising the ability of balance between conservation future generations to meet and transformation to a more their own needs", the heritage issue emerges as one of the considers transformation as the key points. By agreeing with the main tool for conservation of the assumption that we have the task historic cities of the Islamic world. to give to future generations an environmental system able to satisfy their needs, then we must deal with the transformation scientific community about the of the heritage through the urgency to develop researches conservation of the process of its formation, defined, in the Islamic city, in its endogenous selfregeneration process.

has been to shift the current

accurate interpretation that

Receiving the ongoing

international debate in the

blossom of UNESCO and the

and tools for the application

of the new HUL approach

to heritage, the research

aimed to contribute to the

deepening of our knowledge

on the urban environments in

provide a more conscious and

sustainable framework to the

urban development of those

cities and to the conservation

Islamic countries in order to

PhD Yearbook | 2017 79 ARCHITECTURE, BUILT ENVIRONMENT AND CONSTRUCTION ENGINEERING

ADVANCED TOOLS FOR THE DESIGN OF SLIDING ISOLATION SYSTEMS FOR SEISMIC-RETROFITTING OF HOSPITALS

Gandelli Emanuele - Supervisors: Prof. Virginio Quaglini, Prof. Maria Pina Limongelli

The thesis topic deals with seismic isolation and is focused on the characterization of the dynamic behavior of a specific device, the Curved Surface Sliders (CSS). Advanced numerical tools for the design of these systems are developed and applied to a particular case, the seismicretrofitting of hospitals.

Hospitals' full operation after a major seismic event is of primary importance for the management of the post-earthquake emergency. However, recent earthquakes have shown that the traditional approach for the design of earthquakeresistant structures based on the strengthening, though preventing the collapse of the building, may result in severe damages to nonstructural elements and electromedical equipment, eventually compromising the operation of the hospital. On the other side, the "seismic mitigation" approach, consisting in providing the building with base isolation and/or supplementary energy dissipation, has shown to be an effective solution for the protection of hospitals and hospital content from earthquake-induced damages, enhancing their resilience and entailing substantial decrease in time and cost of repair compared to a conventional fixed-base structure.

Among the current hardware

for seismic isolation. Curved Surface Sliders (better known, in North America as Friction Pendulum Systems) present high load-carrying and displacement capacity combined with compact dimensions, an oscillation period virtually independent on the mass of the superstructure, and minimization of torsional effects in case of asymmetric buildings, which make them the most suitable device for seismic retrofitting of existing buildings, like hospitals. Nevertheless, in spite of the large diffusion worldwide occurred in the last decade, a full characterization and modelling of the behaviour of sliding isolators has not been yet completely achieved, and this is also reflected in the codes and in the design tools available to structural engineers. Within this framework, the research mainly aimed at deeply characterizing the actual behavior of Curved Surface Sliders during seismic excitation and at developing numerical tools that can be used by practitioners in the design of sliding isolation systems for seismic-retrofitting of hospitals. The most important milestones of the thesis are briefly described below. **1)** The first achievement arises

from the investigation of the "frictional heating" of the sliding surfaces under

strong earthquakes and the understanding its effects on the coefficient of friction and on the effective damping and stiffness of the device. A 3D thermo-mechanical model of a CSS isolator has been developed in a FEM software (Abagus®) to reproduce the heat flow at the sliding surfaces and the associated temperature increase as a function of friction, pressure and velocity. The model has been validated against the results of experimental tests carried out on full-scale isolators and it is proposed as a preliminary design tool to evaluate the response of the seismic hardware in standard test conditions, to provide valuable information for the selection of friction materials, accounting for their temperature-dependent characteristics. In addition, the model may support laboratory testing of real scale isolators, e.g. for the prediction of the temperature rise history at the sliding surface of the isolator when it cannot be easily measured. 2) A second milestone is related

to another blackspot of the system: its re-centring capability. Existing standards, in fact, propose few re-centring criteria, formulated on empirical

approaches never validated for CSS isolators. In the thesis, the re-centring criterion provided in Eurocode 8 is assessed investigating in a parametric study the dynamic response of the isolation system in presence of an initial seismic or nonseismic offset displacement. The effect of the initial offset on the peak and residual seismic displacements, more evident for high-friction devices, has been quantified. Eventually, it is proposed a refinement of the code's criterion to establish conditions under which the initial offset has no practical effect on the seismic displacement of the isolator.

3) Another open issue in the analysis of structures isolated with CSS seismic isolators is the modelling of the increase in friction at the breakaway. Though this phenomenon is well known, a suitable numerical formulation is still missing in commercial software. Two different approaches have been developed to account for the "breakaway effect". The first approach provides the insertion of elasto-fragile trusses at the isolation level of the building with strength adjusted to match the expected frictional resistance of the isolators at the breakaway. Important outcomes have been obtained applying this simple modelling method to a case study relevant to a threestorey building implementing CSS isolators. Indeed, analyses outputs have shown that, in case of CSSs equipped with medium or high friction sliding material, the breakaway effect

has a significant influence on peak floor accelerations and inter-storey drifts.

- **4)** A more refined approach has been achieved through the development of a new friction model (named "BVNC") capable to simultaneously describe the "breakaway effect" and the damping decay due to the "frictional heating", as well as the dependence of the friction coefficient on the instantaneous sliding velocity and normal load. The proposed formulation has been validated against the hysteretic forcedisplacement curved obtained in experimental tests on fullscale CSS isolators carried out at the SRMD Lab. of University of California, San Diego. Eventually, the formulation of the CSS element available in a commercial FEM software (OpenSees®) has been modified in order to account for the "BNVC" friction model in nonlinear dynamic analyses.
- 5) Moreover, a novel "conceptual design methodology" for seismic-retrofitting of strategic buildings by means of sliding isolation systems has been formulated. The procedure is developed step-by-step and, gradually increasing the complexity of the required calculations, aims at: (a) defining a robust procedure for the design of seismic retrofitting interventions; (b) identifying the optimal solution with respect to specific performance targets for the protection of both structural and non-structural components; (c) evaluating the

effectiveness of the proposed solution (fault tree analysis); (d) obtaining output results more representative of the actual response of structures implementing CSS isolators using refined hysteretic models calibrated by means of experimental data.

6) In the last part of the research, the proposed conceptual design has been tested in the design of an optimized sliding isolation system for the seismic-retrofitting of a real hospital, the "Giovanni Paolo *II*" of Lamezia Terme, located in a high seismic prone area in southern Italy, chosen as case-study. Nonlinear dynamic analyses have been carried out on both the "as-built" and "base-isolated" configurations, implementing, in the second case. the "BVNC" friction model and the modified isolator element. The designed retrofitting intervention is shown to widely improve the overall performance of the hospital buildings; in particular, for low-moderate earthquakes (PGA from 0.17 to 0.22g), the implementation of optimized CSS isolators, in addition to preventing the structural collapse, is predicted to allows the complete protection of non-structural components, and hence the full operation of the hospital in the emergency response. For more severe events (PGA from 0.45 to 0.50g), the adopted solution ensures again the structural integrity and limits the damages to plants with minor effects on the hospital's operation.

PhD Yearbook | 2017

Gobbi Silvia - Supervisor: Prof. Gianandrea Ciaramella

The global crisis had changed the investments of Italian construction firms. A stagnant domestic market had pushed the Italian construction companies to focus their attention into the global panorama. Looking at the current trend of the worldwide market, it became evident that emerging countries were the new market fields and the trades of the construction sector had to reflect the characteristics of the global scenario.

The Italian construction industry is composed by many Small and Medium sized Enterprises (SMEs) that have already, or are willing to, internationalize their business. If the connection between the international business discipline and the construction industry is consolidated, at the big-sized and multinational firms level, scientific literature and current survey outlines the need for more studies on the integration of such a knowledge especially in the architectural disciplines for helping the internationalization of the construction SMEs. The path covered during the research project has embraced different shapes of the internationalization process of construction industry SMEs. By its nature, the strategy for starting a crossborder activity opens a wide range of factors and variables

that are likely to condition the decision-making process carried out by SMEs' owners. The research is developed in two steps throughout a multidisciplinary approach, that join the professional knowledge of the construction market and the scientific tools and methods for the analysis of the internationalization strategies, the first is related to the analysis of three world macro areas (Extra European Union, Middle East and South America) and the second is devoted to identify the entrepreneurial strategies used by a sample of Italian construction SMEs that are working in the three world macro areas analyzed. The data collected on the new global construction customers and on the basis of the frameworks and the analysis developed by the international business discipline on the construction industry, the research aims to define the most appropriate recommendation for the decision-makers about how to enter the construction market of emerging countries. The final output is a model that wants to highlight strength and weakness factors of the entrepreneurial strategies of the Italian construction SMEs as well as to identify the opportunities and threats factors of the market scenario of the three world macro

areas characterized by quite different emerging countries construction markets. The right address of the entrepreneurial energy could create successful cross-border activities and in this sense the development of academic relationships could be useful for helping the Italian construction SMEs internationalization

A NEW DESIGN APPROACH FOR CONCENTRICALLY **BRACED FRAMES IN MODERATE SEISMICITY**

Kanyilmaz Alper - Supervisor: Prof. Carlo Andrea Castiglioni

Concentrically braced frame (CBF) configuration is very effective for resisting horizontal loads. Under earthquake actions, its high lateral strength and stiffness provide an abundant safety for steel buildings. In order to maximize the performance of CBF buildings under strong earthquakes, extensive research has already been conducted. Indeed, current European Codes have guite advanced ductility rules for CBF structures. However, although these structures are very popular in the moderate seismicity regions of Europe, in this context, the building codes do not provide specific design requirements. While the strong ground motions are relatively well quantified, with sufficiently developed and comprehensive design procedures, nothing comparable exist for moderate ones. This lack of knowledge combined with the vulnerability of high urbanization in moderate seismic areas causes a big risk for the people. In the moderate seismicity context, engineers must choose between a "non-dissipative" method neglecting all seismic provisions (DCL), and a "high-dissipative" one, applying its complex and expensive ductility requirements (DCM). Currently the preferred method is the former one, because of its simplicity. Such a choice may lead on one side to

oversized profiles that are unduly expensive, on the other side to unsafe solutions with significant life-safety consequences due to the unpredictable nature of the regions characterized by moderate seismicity, where rare but strong earthquakes are foreseeable. On the other hand, enforcing engineers to apply strict "high-dissipative" rules seem too conservative for this case, which would result in oversafe, but uneconomic structures. Considering that CBF systems are the most common configurations in the European steel construction market, such a situation gives rise to the need of an optimized design, with specific rules more compatible

with the buildings located in areas prone to moderate earthquakes. This thesis proposes a new approach for the moderate seismicity design of CBF structures, aiming to satisfy both economy and safety criteria. The proposed approach is based on the exploitation of the three features of CBF systems, whose knowledge is not yet sufficient to use them as reliable sources in the design: "frame action provided by gusset plates", "contribution of compression diagonal and its post-buckling strength and stiffness", and "energy dissipation capacity of non-ductile bracing joint connections". The thesis



a. MRF test specimen

1. Pictures of the test specimens

b. PC test specimen

investigates these aspects by means of full scale experimental tests (Figure 1) of one-level specimens, and numerical analysis with incremental dynamic analysis method of calibrated multi-story building models. As a result of the experimental and numerical studies, the thesis provides new design recommendations, and presents economic comparisons between the buildings designed with current Eurocode approach and the proposed one. Experimental and numerical findings of this thesis resulted in a final proposal of a "DCL+" approach for the design of CBF systems in moderate seismicity regions. The additional requirements of this method with respect to current "DCL" are the following:

- i) Gusset plates should be designed to remain elastic, and engage efficiently the beam-tocolumn connection.
- ii) Upper limit of bracing slenderness should be kept as 2.25.

iii) Bracing joints should be designed with a capacity ratio of at least 0.7, and these joints should be pre-loaded (category B or C of EN1993-1-8).

iv) If the above three requirements are met, a behaviour factor (g) of between 2.50 can be allowed. thanks to the exploitation of the benefits of the frame action, compression diagonal, and bracing joints.

Table 1 shows the cost comparison between three building types studied in this thesis (DCL, DCM, and DCL+). In the first eight rows of the table, calculations are shown with reference to the plane braced frame with 4 floors. Then in the last three rows, the results are extended to the whole building. Bracing costs are 195.7% higher in DCM with respect to DCL. For DCL+2, they are higher by 52.1%. Assuming



drift curves

2. Comparison between "DCL" and "DCL+" approach

TABLE 1 COST COMPARISONS DCL DCM DCL+ Bracing profile weight (tons) 0.55 1.63 0.92 Bracing profile cost (€) 826 2451 1384 Bracing joint material cost (€) 288 806 358 275 Bracing joint assembly cost (€) 211 619 Plane frame (4 floors) Total bracing joint cost 499 1426 634 Subtotal sum (€) - Bracings 3877 2017 1325 0 Saving at fabrication phase (€) 14 23 Total sum (€) 1311 3877 1994 Total sum for 4 braced frames (€) 5245 15507 7977 All building Cost increment of bracings +195.7% +52.1 % Cost increment for steel structure +7.8% +2.1 %

behavior corresponds to a cost increment of 2.1 % for the steel structure budget. 0,6 0.45 (**6**) **6** 0.15 - "DCL+" Drift (%)

b. Inter-story drift vs scaled

acceleration curves

that the bracings influence the 4%

configuration costs +7.8% more for

the total structure budget. This total

cost increment with respect to DCL

Figure 2 compares the global

performance of a case study

designed with current "DCL"

and new "DCL+" approaches by

means of average IDA curves. The

improvement in global behaviour

and decrease of collapse risk with

the "DCL+" method can be noted.

"DCL+" design is much more robust

and ductile, and enters the collapse

zone at much higher accelerations.

This improvement in the structural

is only 2.1% for DCL+.

of total structure costs, the DCM

BUILDING SIMULATION MODEL IN CONTROL SYSTEMS FOR ENERGY EFFICIENCY

Marenzi Giorgia - Supervisor: Prof. Massimiliano Manfren

While new paradigms for the construction sector are emerging, such as that of "Nearly Zero Energy Building" and sustainability assessment schemes are progressively evolving and becoming more common, empirical studies show how, very often, the gap between the predicted (design phase) and measured (operation phase) energy performance could be very large. This issue is generally addressed with the term "performance gap" and it can be fundamentally caused by design phase, construction phase, commissioning and operational phase errors.

Generally, the decisions that have the greatest impact on total facility cost and energy demand are made early in the design process, without understanding their overall impact of performance during building life cycle. A technical issue is determined by the lack of software to quickly and accurately simulate building energy performance, considering appropriately the uncertainty of the input data assumed. In fact, in the Architecture, Engineering and Construction (AEC) sector, several computational tools are used in the design phase but they lack integration, although several efforts are ongoing to

include more advanced features in Building Information Modeling (BIM). Further, Building Energy Modeling (BEM) tools are not generally used at present for the design of control and diagnostic systems suitable for operation phase, although research activities are ongoing. Additionally, building simulation tools are not generally used throughout the life cycle for the verification and benchmarking of building performance due to the difficulties in model calibration and comparison. Therefore, there is a missing link among models suitable for performance optimization and monitoring across life cycle phases. This situation creates a problem of credibility in the building industry and, more in general, in sustainability practices because the errors committed can directly reflect on energy performance and, consequently on the running costs and on global cost optimality. Bridging the gap between simulated and real energy consumptions requires the presence of embedded control and fault detection applications that have to be adaptive, self-calibrating and conceived to enable a model based interpretation of measured data, for performance benchmarking. Currently, in the AEC sector,

state-of-the-art methods and models used in other sectors. such as optimization techniques for design and advanced control, are not widely used. The optimization of the dynamic operation of a building or of a cluster of buildings requires the definition of suitable models that can be solved by high performance solvers in realtime. Of course, domain specific model reduction techniques are required and uncertainty and sensitivity analysis should be taken into account as well in model verification, validation and calibration.

Finally, data driven models for fault detection, diagnosis and prognostics are generally not conceived for multi-scale applications and for being integrated and synergy with optimization models. Therefore, a further effort of integration in this sense is necessary. Considering these general issues, the aim of the research is to find

a simple and understandable method able to create a dialogue with both control and energy simulation fields in order to fill the gap between the predicted (design phase) and measured (operation phase) energy performance. Furthermore, a very important intend is to find the main data needed by the building model in order to guarantee a good control result (in a predictive perspective) and a calibration method able to verify whether the model simulates effectively the actual trend.

The methodology used for the research, therefore, seeks to unite different moments of energy management (predictive control and data analysis) through the choice of effective tools, able to interact each other, trying to unify methods and models used in different fields and understand how to make them usable in an effective workflow across life cycle phases.

In general, direct and indirect building energy models are described, analyzed and validated in order to have a tunable Model Predictive Control (MPC) able to optimize the energy consumptions during the operational phase. The MPC, in fact, is tunable through a data analysis workflow presented. Further, the overall method is applied to a real case study. In detail, starting from a linearized lumped parameters model, the building energy dynamics is simulated and an optimization algorithm is used to find the optimal operation trajectory that satisfies the constraints while minimizing energy demand. Using a Linear Programming (LP), in fact, it is possible to find the best possible solution given the specific conditions (i.e. find a solution that is certainly a global optimum). Further, the optimization model used, working on set-point violations, can be, in principle, simply added with an additional layer on existing automation

systems, without having to replace completely the technology, but simply working on the top of conventional PI/PID controllers. Then, in the data analysis workflow presented, two main levels of model calibration are done; firstly, with monthly data the main lumped parameters are analyzed through regression models and, secondly, using hourly data, an identification technique (ARX model) is used to directly calibrate/ build the whole model (suitable for multiple temporal scale of analysis) with the estimated parameters. In this sense, we can think about a workflow in which there is an overlay of long-term performance monitoring, with low-frequency data (i.e. monthly, daily), and short-term model recalibration based on detailed high-frequency data (i.e. hourly, sub-hourly). An important feature of regression models is that they can work online, and, thus, they can periodically selfcalibrate and give a feed-back on performance, while the ARX model is helpful to dynamically reconstruct the energy model suitable for optimization starting from actual hourly data. By analyzing the data, it is possible to perform Fault Detection and Diagnosis (FDD), assuring both a good performance of the control system and a prompt corrections in case of energy performance deviation during the operation phase. Parameter identification allows also to analyze the evolution of parameters over time, and, thus, lay the foundations for a machine learning system application which may constantly improve

the control system knowledge adapting and learning to building and end-users characteristics. The energy demand reduction, however, is not the only objective to be pursued. Internal environmental guality and energy savings can be conflicting objectives and comfort expectation can cause an "economic rebound effect", limiting the energy saving potential of efficiency practices and, therefore, compromising the return of investment. The Predicted Mean Vote (PMV) evaluation acquires a crucial role in the choice of the limits to be set in the optimization algorithm. The latter in fact, needs a limit in terms of degree/days and degree/ hours of comfort violation that can be chosen starting from a comfort assessment, done through the PMV evaluation.

The advantages provided by a Model Predictive Control (MPC) system such as the one presented in this research are also dependent of the type of objective function adopted. Starting from the minimal energy demand, in fact, it is also possible to minimize costs (using dynamic tariffs) and emissions (using hourly CO₂ emission time-series and emission factors) or considering a combination of both, using weighting factors. Further, it permits to increase the overall energy efficiency, considering both the load matching and the dispatch flexibility problem. As a conclusion, the research aims to give a contribution in the building energy efficiency field, but considering a wider perspective on the use of data at the building scale.

A BUSINESS MODEL FOR SOLAR THERMAL FACADES

88

Passera Alessio - Supervisor: Ing. Roberto Lollini

As stated in several research projects, building envelope systems may have a great impact in terms of energy performance and economics for both new constructions and building refurbishment. However, there is still a lack of tools supporting an easy life cycle costs analysis and the assessment of economic risks linked to the integration of energy delivering components like photovoltaic panels and solar thermal collectors, mainly due to the uncertainties about the variability of cost and value parameters and about subsidies and responsibilities. This makes business models based on the potential of active facades an extremely actual research topic. Such a potential is linked to the façade as energy delivery system, where the centralized system turns as back-up element. The scarce success of innovative façade solutions is sometimes due to the difficulty to communicate the integrated energy concept among façade stakeholders. However, the complexity introduced into the building envelope fears designers and façade manufacturers. The real technical feasibility of solar active façade concepts still needs to be investigated. That is why this research project have come up with a userfriendly tool thought to bridge the gap in communication between designers and facade manufacturers and investors. The instrument focuses on active solar facades and it is called FAST-IN tool (Feasibility Assessment of Solar Technologies Integration). The tool illustrated in the thesis is an original instrument allowing designers, façade builders and investors to assess the economic impact over time of several scenarios in terms of technology, maintenance and economic parameters variation. Technologies refer to solar active façade concepts, passive façade solutions and energy systems. One of the aims of FAST-IN tool is providing performance indicators related to active facade solutions based on dynamic calculations. A unitized solar thermal façade system was chosen as reference technology to develop a business model to be afterwards generalized to solar facades. The façade is supposed to be the skin of office buildings. This multifunctional system provides solar heating when sun is available and heating needed, solar Domestic Hot Water (DHW) and storage, and space heating and cooling through the radiant system thanks to the auxiliary centralized energy system. The integrated components are: (i) a

standard solar thermal flat plate glazed collector, (ii) an insulated water storage located behind the solar thermal collector, (iii) a radiant panel system installed as inner component The façade system has been designed and developed within a project called Sun-RISE, co-funded by the province of Bolzano, involving the Institute for Renewable Energy (EURAC) and the façade manufacturer Stahlbau Pichler.

The assessment of the façade system goes through: (i) a technology analysis to understand risks during the design process and requirements; (ii) an economic analysis to identify avoided and extra-costs in comparison to standard solutions, and to investigate on possible financial schemes; (iii) a performance analysis focused on energy uses and thermal comfort. Within the project framework, a prototype of the façade case study was built by the manufacture Stahlbau Pichler. Test activities to investigate the thermal performance of the façade system are part of the project. The unitized facade subject to tests is 2143 mm wide and 2880 mm high. The figure shows the facade prototype installed within the EURAC testing facility.



1. Facade prototype within the EURAC test facility

The thermal performance of the opaque portion of the facade case study was investigated through thermal analyses. A 1-D study showed that inwards heat fluxes contribute to reduce the heating demand in the range of 9% to 4% by increasing the insulation thickness, while cooling load decreases from 32% to 16% if insulation resistance is increased. The methodology used to assess the performance of façade design solutions starts from the office room scale. A TRNSYS mono-zone model was created to simulate an office room and quantify the energy performance associated to different façade configurations in terms of window to wall ratio, glazing typology, active surface

area and orientation. This preliminary activity is a necessary step to populate the database of results included in FAST-IN tool. Once the number of office rooms has been specified and the facade has been configured and the building size fixed, the user may specify choices related to the facade and heating and cooling system. The financial scheme and the economic parameters varying the cash flow structure are also defined to calculate the net present value of the proposed envelope solution. The user may also set a sort of maintenance plan, changing building components' lifespan, and assessing its influence on the cash flow trend in the first 50 years of life (the final output). A 40-rooms office building located in Bolzano (Italy) was hypothesized as building case study to apply the tool and to assess different design solutions. The thesis compares the base line solution with an application of a BIPV façade coupled with a heat pump for heating and cooling and fan-coil units. Assumptions regarding government contribution to cover active technologies costs and reevaluation of the rentable space were done. This application showed clearly

This application showed clearly the advantage in using the photovoltaic façade coupled with a heat pump. Compared to the energy produced from solar thermal collectors and directly used inside the building, the photovoltaic scenario leads to a 60% higher use of the produced energy. The same study in a northern location could reverse the result. It is important to highlight that the tool was not originated to justify a specific technology integrated into façade. The aim of the tool is quantifying benefit and constraints of design solutions with solar façades during the early design stage considering since the beginning the performance-economic analysis during a specific lifespan. The potential of the tool is associated to the easiness of comparing envelope solutions and building energy systems in a life cycle costs perspective. Economic parameters such as discounting back rate, projectfunding instruments (mortgage, third party loans), energy related subsidies, rent increase and others can be varied to assess the variability of an investment. As every instrument in its early stage, the structure needs to be improved by means of applications. The costs database requires a continuous update and input to consider different markets and regions.

HEALTHY URBAN MOVES. ASSESSMENT TOOL OF CITIES' WALKABILITY TO IMPROVE ACTIVE TRANSPORT AND PHYSICAL ACTIVITY IN URBAN AREAS

Rebecchi Andrea - Supervisor: Prof. Stefano Capolongo

Background

Recent studies in Public Health have focused on how the built environment influences population's physical and mental health; in particular, many European researches have studied the correlation between health status, the healthy behaviour of its inhabitants and the characteristics of urban space. Active Transport and Physical Activity, for example, a favourable behaviour for prevention of chronic diseases, is strongly influenced by a walkable urban space, that may reduce the negative effects of the built (against the natural) environment and generate positive ones.

Objective

Aim of the research is an urban assessment tool that measures cities' walkability, able to highlight the weaknesses and strengths that characterize the structure of the urban environment analysed. The

tool refers to all the aspects that have a direct influence (evidence based) in fostering the healthy lifestyles' adoption, or promoting Active Transport as a strategy to increase the level of Physical Activity due to daily urban travels, with positive impacts on the population's health status.

Research method

A series of existing assessment tools were examined and compared, in detail. Then, a critical selection of different qualitative and quantitative indicators was found and compared. On this basis, a new evaluation tool was defined and weighted, by a panel of experts: The research developed a multi-criteria evaluation system of the urban environment, able to assess the walkability at Macro (city) and Micro (neighbourhood) scale, identifying a series of indicators that may have implications on

health promotion. The new tool, usable in different urban contexts, has been tested in two different areas of Milano city.

Results

Outcome of the research are design recommendations, based on gualitative and guantitative collected data, useful to Policy Makers in supporting evidencebased urban planning choices and, at the same time, to designers who may identify which aspect of the urban environment has to be improved or changed, to promote healthy walkable city.

Keywords

Urban health; Healthy cities; Health promotion; Non-communicable disease (NCD's) Prevention; Active Transport; Physical Activity; Walkability; Assessment Tool; Community-based land use strategies; Evidence based public health (EBPH)



Grafici di potenziale MACRO e MICRO

94%

Diversity Politecnico



ADAPTIVE SHADING DEVICE FOR HIGH PERFORMANCE BUILDING ENVELOPE

Speroni Alberto - Supervisors: Prof. Tiziana Poli, Prof. Greg Blonder,

it spatially to supply a glare-

Prof. Andrea Giovanni Mainini

Keywords

Shading device, Shape Memory Alloy (SMA), Smart Material (SM), User comfort, Daylighting, Building Envelope, Local activation, Outside view.

Problem statement

Sunlight is a natural resource of energy which we need to allow into our buildings through glazed apertures as daylight for visual tasks. The sunlight energy density varies over a wide range, and has to be controlled to prevent overheating but, at the same time, a vital connection with the outside world should be maintained (feeling of users of external environment).

A large proportion of office buildings' energy consumption is due to lighting (26% of total energy usage for commercial buildings), so it is important to use daylight whenever it is available. On the other hand, solar gains are a widespread cause of overheating in buildings and they create a large cooling energy demand for air-conditioned buildings. Shading and solar control can resolve the challenge to get sufficient daylight into the building while avoiding glare and unwanted heat gains. The issue is to modulate sunlight, and possibly to re-distribute

free working illuminance for a minimum summer heat gain. This is what solar control should address, and it is achieved by shading devices, in or close to the window opening, that reduce the overall transmission of the window by obstruction or through transparent or translucent layers. These devices play a key role in the building envelope in term of performance, but also in users' comfort. These can be both static and dynamic and can have different positions (external, internal), multiple arrangements (vertical, horizontal) and activation rules.

Nowadays dynamic systems are the most preferred and are based on electric-mechanical systems. A current school of thought considers the introduction of smart materials (typically shape memory alloy, shape memory polymers and thermos bi-metals) as an alternative to motors because can make the shading system efficient reducing the risk of failure, but, in order to do that they have to be more than a simple substitution of the engine: a tailor made new shading functional model based on SM properties is required. The existing systems define new design possibilities of shading

systems with integrated smart materials showing effective ways to integrate it. Their level of development is different and in some cases the testing phase needs to be improved. These are still complex, and both the costs for SM and the cost for electricity for the active ones are high.

Research project

The aim of this research project is to develop a passivedynamic shading system that could be tailored to respond to standard project parameters, complemented by behavioral models that describe its performance characteristic profile (in term of both energy performance and daylighting). These results can be achieved designing a shading system that integrates Smart Materials (SM) and is based on a bi-stable working principle. The integration and application of this new shading system within buildings' context should: reduce or remove the energy need for the shading system movement, while ensuring adequate daylight performance, fulfilling users' requirements and minimize system's complexity through an optimization of the number of components reducing the risk of failure and considering the aspects of maintenance and

management.

In order to define the parameters (input) required for the development new shading device components, three main activities were performed: state of the art and SMs' analysis, optical measurements for shading materials and energy simulations. The first activity consists of the analysis of state of the art for static and dynamic shading devices systems and of the smart materials used for shading systems followed by a deep analysis of their efficiency. The second activity is the analysis of the optical properties of traditional and innovation shading materials. After a selection process, materials have been optically characterized through the use of an Ulbricht sphere and a spectrophotometer. These measurements allow for the division of the materials into different classes dependent on optical behavior. The third activity consist in the preliminary simulations conducted in order compare the response in different scenarios (location, orientation, WWR) of the glazing systems alone with the shading system technologies. All the results obtained in these initial three chapters are the basis

of the development of the new system and defined the three main aspects for an innovative SM based shading system. These activities were followed by the selection of the SMA wire as smart material and the definition of a new functional model that optimize the material features. This model has been improved step by step partially changing its

features and structure following an iterative process. The final system developed consist in: a central hinge (the core of the system that support the shading material and is directly conncted to the SMA wire and blocking system), a blocking system (a custom component that allows to reduce both the energy need and the shading material stresses), a shading material (it can be made by all the standard or innovative shading materials and it can assume all the shapes choosen by the designer - planar or 3D) and the SMA wire + bias spring (the actuator element that makes it dynamic).

An adequate design of these elements allows to customize the system for many different scenarios. The variables have two different levels: the first one deal with the building facade scale while the second one to the system itself. For what concern the building facade the possible customization deal with: position (inside, double skin or outside), frame (existing facade frame or custom frame), façade possibilities (flat, curved or free form façade), WWR (all the WWR). The system variables are: arrangement (vertical, horizontal or custom angle), panel dimension (form 0,01 [m2] to 0,25 [m2]), shading materials (all the traditional shading materials), % of flaps opening (completely open, custom open angle), shape (all the possible shape also 3D), activation rules (single, multiple or random activation).

The results obtained show advancements compared to the state of the art. The main results obtained for the new system are:

- the bi-stability working principle reduce the system complexity and the requirements of SMA wire (using 26% of a SMA based system with same delta openness factor);
- the use of a blocking system introduces advantages because avoid the use of a chopper system (complex element) reducing the energy need (25% of a standard roller blind and 0,3% of an active shading system with SMA);
- the definition of new custom activation rules for a local shading system based on the users' needs increase the system effectiveness in term of comfort considering not only glare but also outdoor view (compared to a VB system a local -opaque- shading system increase until a peak of 34 % with same glare standards);
- the daylighting simulations carried out (the reference case is a single office unit 3x3x4 [m], WWR 100%, placed in Milan with south exposure) shows out the flexibility of the system can answer to different use needs. The input of increase the DA preserving a no glare condition has been achieved with 0% DGP and 86% DA (7% more than a traditional Venetian Blind).

PhD Yearbook | 2017

EVIDENCE BASED GEO-DARM (DATA & ARCHAEOLOGICAL RESEARCH MANAGEMENT) MODEL FOR MULTI-USER DATA SHARING

Valente Riccardo - Supervisor: Prof. Raffaella Brumana

The thesis aims at investigating a possible reconsideration of archaeological potentialities considering the use of digital surveying for archaeological purposes and supporting it with theoretical assumption about the role of cultural objects coming from different disciplines, such as cultural psychology.

Archaeology, as investigation discipline, produces a large amount of data about the material remains of past human life and activities. A large part of this data is produced during excavation activities, one of the disciplinary pillars on which archaeology is grounded. Archaeological excavations require not only academies but also a larger cultural management framework which concerns national regulations, public bodies, private companies and other subjects involved with archaeological excavations. Most of recent excavation s are development-led projects, with different needs than research excavations for what concerns timing, funding and management; these elements make developmentled excavations depending on developers' needs, and good compromises between commercial and research perspectives are not always easy to be found. Among field archaeologists is still widespread the use of manual surveying techniques, which are

inevitably less accurate and more time-consuming than advanced ones, a point which is often critical in commercial excavations. In Italy, shared standard for the production and the management of the

archaeological data are still largely missing, while the access to them is often restricted, despite the several calls for a better openness: there is also a relevant lack of available data in digital formats, and this aspect does not help an easier access and use; the result is that most of the commercial excavations remains substantially unpublished and scarcely known. Both standards and open data depends on the methods with which data are collected and this phase, i.e. the on-field documentation, highly influences all the successive steps of research.

The thesis proposes a feasible methodology for archaeological documentation, including a practical procedure for the use and testing of digital tools for archaeological purposes, backed by theoretical contributions on the nature and the role of archaeological evidences. Since the archaeological practice is based on a continuous activity of selection and removal (excavation) but at the same time is focused on the preservation of material culture, these topics have been presented. Cultural objects have

also a relevant impact on human beings, influencing and shaping both individual and collective identities. The belonging of stratigraphic elements, such as soil layers and feature interfaces, to material culture has been discussed, as well as their cognitive nature. On one hand, they could be considered as belonging to material culture as a material product of human actions. On the other hand, stratigraphy includes both material and immaterial elements; furthermore, deposits and feature interfaces lack of some fundamental properties of objects, and this aspect often prevents their consideration at the same level of other archaeological objects such as findings and structures. They are constantly removed by the archaeologists themselves in order to carry on the investigations. Chances to experience them is very limited, except for archaeologists and there is a sort of contradiction in preserving materiality (such as findings or structures) and removing other evidences (soil deposits). Archaeological selection is, for the moment, unavoidable to increase knowledge and discoveries; despite this, is a change in the perception and the documentation strategy possible in order to reduce the material loss of the stratigraphy? The inclusion of stratigraphic elements



among cultural objects with digital surveying and modelling technologies is proposed, as well as a theoretical model which presents the possible impact of an enlargement of the category of cultural objects. Since cultural objects have an important role in the management and creation of human personal and collective identities, this aspect helps in supporting the entire proposed digital recovery of stratigraphy, opening to a reconsideration of the cultural role of stratigraphy and its documentation.

A feasible methodology aimed to improve the archaeological research is proposed, based on the use of digital photogrammetry and topographic measurements in substitution of manual surveying. This application assures better results in terms of accuracy on the field, relevant savings in terms of time and a great interoperability which helps a better use, analysis enhancement and communication of data. For instance, from some photogrammetric outputs, such as orthophotos, it is possible to realize detailed archaeological



to the enlargement of cultural

evidences previously presented.

Possible users and beneficiaries

researchers; common audience)

are also presented, each one with

(field researchers; desk-based

its characteristics and needs.

a nementa n Nementa n Nementa n Nementa neme

The method is adaptable with most

PhD Yearbook | 2017

95

of the actual Italian regulation that defines archaeological documentation, that mainly aims to simplify the possible dissemination of results and data coming from archaeological excavations. Moreover, the method provides a feasible and cost-sustainable approach for field and post-excavation activities. It goes towards an object-based approach for archaeological documentation, overcoming, at least in certain cases, the traditional two-dimensional outputs. It allows an important digital interoperability able to widen the results of research. It proposes also different consideration of the values of the archaeological evidences, important not only at a theoretical and intellectual point of view, but also to reevaluate the archaeological heritage discovered during commercial excavations. Proposals and results are presented and discussed, also displaying the results of field tests carried out during a two-years archaeological campaign on the San Calocero site in Albenga, one of the most important archaeological site in Liguria, which involved several academic institutions and researchers.