Dept. of Energy, Systems, Territory and Construction Engineering (DESTeC)
University of Pisa – 9th November 2012 – Pacinotti room (10:00-11:30)

EUropean Civil Engineering Education and Training association

EUCEET association workshop
"Innovation in Civil Engineering Education"

EUCEET Association

Role of BUILDING PHYSICS in the Civil Engineering Curricula

Mec Eng PhD **Fabio Fantozzi** (*Full Professor*)
Civ Eng PhD **Francesco Leccese** (*Assistant Professor*)

Il Settore Scientifico Disciplinare

(Fisica Tecnica Ambientale = Building Physics)

… Il Settore studia gli aspetti fondamentali ed applicativi della termodinamica applicata, della termofluidodinamica, della trasmissione del calore, dell'energetica, della fisica ambientale, dell'illuminotecnica e dell'acustica applicata con riferimento alle problematiche tecnologiche proprie degli ambiti dell'ingegneria, dell'architettura, del disegno industriale, della pianificazione territoriale e dell'agraria.

Fisica Tecnica Ambientale: Fondamenti e applicazioni della Fisica Tecnica negli ambiti dell'ingegneria civile, edile ed ambientale, dell'architettura, della pianificazione territoriale e del disegno industriale. L'approfondimento scientifico caratteristico riguarda i fondamenti della termodinamica, della termofluidodinamica, della trasmissione del calore, dell'illuminazione e dell'acustica, nonché l'uso razionale dell'energia, l'impiego delle fonti energetiche rinnovabili e le tecniche di gestione dei servizi energetici negli edifici e nei contesti urbani. In particolare vi trovano corretta collocazione studi e sperimentazioni relativi alla fisica degli edifici e degli ambienti confinati, al rilevamento ed elaborazione dei dati ambientali, all'energetica edilizia, alla termofluidodinamica ambientale, alle tecniche e alle tecnologie per l'illuminazione naturale e artificiale, all'acustica edilizia e ambientale, alle problematiche di comfort ambientale e di conservazione dei beni culturali, alle strategie passive e attive di controllo ambientale, agli impianti di climatizzazione. Sono attinenti al sottosettore le tematiche fisico-tecniche correlate alla pianificazione energetica ed ambientale, nonché le metodologie di diagnosi e le tecniche di mitigazione degli impatti ambientali, inclusi quello luminoso e quello acustico.

Decreto Ministero Istruzione Università Ricerca (DM 336/2011 - Allegato B)
Area 09 – Macrosettore 09/C
Settore concorsuale – 09/C2 FISICA TECNICA

BUILDING PYHSICS

(second year, first level Course in Civil Engineering, 90 hours)

The aim of the course is providing the students with basic elements on the following matters: thermodynamics, heat transfer, thermal insulation and energy consumption in buildings, humid air, indoor hygrothermal comfort, cooling of buildings, moisture behaviour of building components, daylighting and artificial lighting, room acoustics, sound insulation in buildings. The basic elements are integrated with applications (technical standards) and exercises.

(italian version)

FISICA TECNICA AMBIENTALE

L'insegnamento si propone di fornire nozioni di base sui seguenti argomenti: termodinamica, trasmissione del calore, isolamento termico e risparmio energetico negli edifici, aria umida, benessere termoigrometrico degli ambienti, climatizzazione degli ambienti, dimensionamento igrometrico dei componenti edilizi, illuminazione naturale e artificiale degli ambienti, illuminazione urbana e inquinamento luminoso, acustica delle sale, isolamento acustico degli edifici, rumore ambientale e inquinamento acustico. Normativa tecnica. E' previsto un laboratorio in cui i vari argomenti sono approfonditi con applicazioni ed esercizi.

LIGHTING AND APPLIED ACOUSTICS

(second year, second level Course in Civil Engineering, 90 hours + 30 hours training)

In the first part of the course are studied the fundamentals of lighting (performance parameters, lighting calculus, lighting sources, lamps and luminaire, visual comfort), day and artificial lighting of rooms and workplaces, architectural and urban lighting, light pollution. In the second part of the course are studied the fundamentals of acoustics (sound waves, sound levels, psychoacoustics, acoustics sources and materials), transmission loss of walls, sound insulation in buildings, room acoustics and reverberation time, environmental noise. The lessons are integrated with simple exercises, applications of lighting and sound design of buildings, use of technical instruments (e.g. luxmeter and sound level meter) and technical standards, modelling software.

(italian version)
ILLUMINOTECNICA E ACUSTICA APPLICATA
Nella prima parte del corso vengono studiati i problemi relativi alla progettazione illuminotecnica degli ambienti interni, sia in luce naturale che in luce artificiale, e alla progettazione illuminotecnica degli ambienti esterni, con particolare riferimento all'illuminazione architettonica e urbana. La seconda parte del corso è dedicata alla progettazione acustica delle sale, all'isolamento acustico degli edifici, alla protezione dai rumori negli ambienti di lavoro e alla propagazione del rumore negli ambienti esterni, con particolare riferimento al rumore ambientale e all'inquinamento acustico.

THERMAL SYSTEMS IN BUILDINGS

(second year, second level Course in Civil Engineering, 90 hours + 30 hours training)

The aim of the course is to provide the students with elements on the following matters: heating and air conditioning systems in buildings, mechanical ventilation and indoor air quality, solar systems in buildings (i.e. thermal solar collectors, photovoltaics cells), low enthalpy sources (e.g. geothermal systems, …), energy performance of buildings and technical standards, outline of thermal systems safety and others (e.g. gas supply, electrical and fire-protection systems, …).

(italian version)
IMPIANTI TERMOTECNICI PER L'EDILIZIA
L'insegnamento affronta i seguenti temi: impianti di riscaldamento e condizionamento dell'aria nell'edilizia, ventilazione meccanica degli ambienti e qualità dell'aria interna, sistemi solari negli edifici (p.e.: collettori solari termici, sistemi fotovoltaici), utilizzo di sorgenti a bassa entalpia (p.e.: impianti geotermici, ?), prestazioni energetiche degli edifici e normativa tecnica, cenni sulla sicurezza degli impianti termici, cenni su altri tipi di impianti negli edifici (p.e.: impianti gas, impianti elettrici, impianti antincendio).

Energy performance of buildings

- Performance and energy rating for buildings of residential and tertiary sector.
- Procedures for analysis of energy consumption in existing buildings.
- Study of the dynamic thermal insulation of multilayer walls and ventilated facades and roofs.
- Use of reflective materials to improve the thermal behavior of the building.
- Analysis of ventilation systems to improve the summer thermal comfort in buildings.
- Analysis of the energy behavior of the building-thermal plant system in non-stationary conditions.
- Evaluation of hygrothermal comfort and air quality parameters.
- Exploitation of low enthalpy thermal sources in air conditioning systems.
- Active solar systems for energy production in buildings.
- Use of renewable energy sources (e.g. wind, biomass, cogeneration…) in the building.

Lighting and acoustics

- **Artificial and day- lighting in indoor work places.**
- **Ergonomics of vision and lighting of workstations with display screen equipment** (DSE)**.**
- **Urban and architectural lighting.**
- **Study of street lighting and light pollution.**
- **Analysis of energy consumption of lighting systems** (LENI index)**.**

- **Architectural acoustics** (room acoustics and sound quality)**.**
- **Design of variable acoustics rooms.**
- **Analysis of sound insulation in buildings and acoustical rating.**
- **Environmental acoustics and noise pollution** (analysis of sound propagation in the external environment)**.**
- **Study of human noise exposure in the work places.**

T.E.A.

building physics and ThErmAl systems laboratory

(laboratorio di TErmofisicA dell’edificio e impianti)

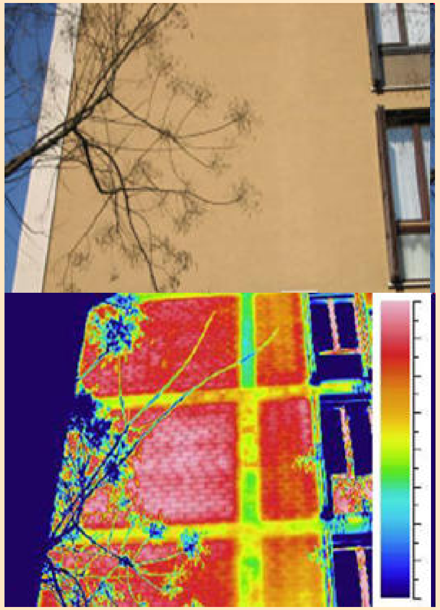
L.I.A.

LIghting and Acoustic laboratory

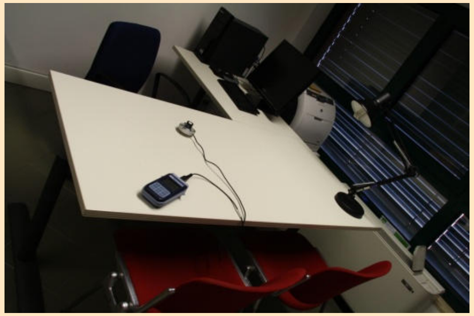
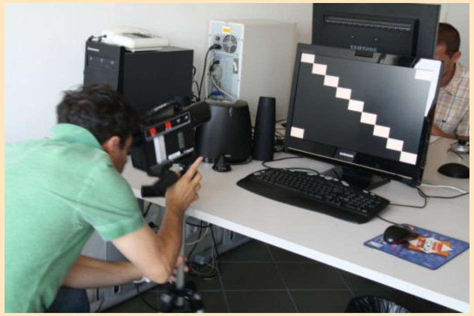
(Laboratorio di Illuminotecnica e Acustica)

- Investigations with infrared thermography:
  - for energy audits of buildings and thermal plants,
  - on the state of conservation of cultural heritage,
  - for structural diagnosis,
  - for condensation problems in walls .
- Measurements of thermal transmittance of building walls.
- Measurements of temperature and relative humidity.
- Measurements of air speed in indoors.

- Thermo-hygrometric design of opaque walls and windows by software.
- Analysis of thermal performance of building components with finite element methods (e.g. STRAUSS software).
- Simulation of air distribution in air-conditioning problems with CFD (e.g. FLUENT).
- Thermal plant design with advanced calculation software (e.g. Energy Plus, Ecotect, ...).



- ➔ Measurements of luminance and illuminance in outdoor and indoor workplaces.
- ➔ Measurement of daylight factor in school buildings.
- ➔ Measurements of luminance in streets lighting.
- ➔ Lighting measurements in museums.
- ➔ Lighting design with advanced calculation software (e.g. A.D.E.L.I.N.E., Dialux, Relux, ...).

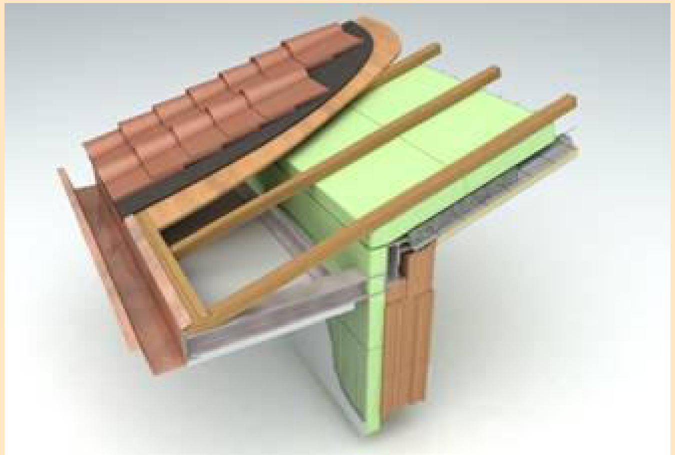

- ➔ Measurement of reverberation and acoustic requirements in the halls.
- ➔ Measurement of sound insulation of building structures, impact sound level, plants noise.
- ➔ Measurement of acoustic characteristics for highway noise barriers.
- ➔ Measurements of human exposure to noise in workplaces.
- ➔ Acoustic design with advanced calculation software (e.g. ODEON, CATT Acoustic, Raynoise, Zorba, ...).

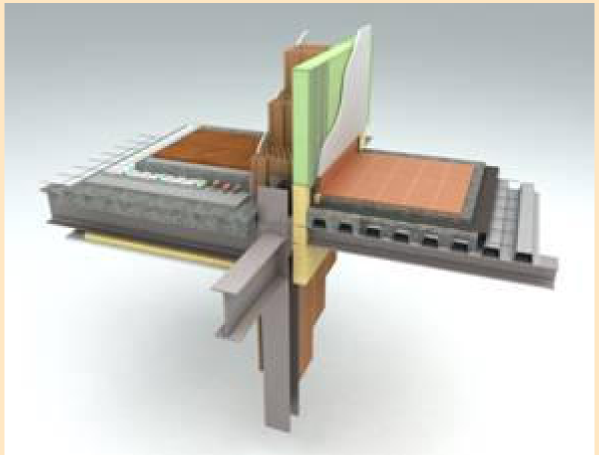
… some examples of master degrees

In this study the Authors describe an interesting case study relating to the proposal for the realization of two residential building interventions with an energy demand for space heating lower than 40 kWh/m^2year. The experimental intervention has been supported by the Building contractors TOGNOZZI ENGINEERING (Firenze) within the Regional Plan “20.000 Houses for rent” in Greve in Chianti (Firenze). It is very interesting to notice that the Town Administration of Greve in Chianti has stimulated, on the basis of the case study described in this paper, the promotion of the design of low-energy-consumption buildings with the adoption of a new Town Building Code.

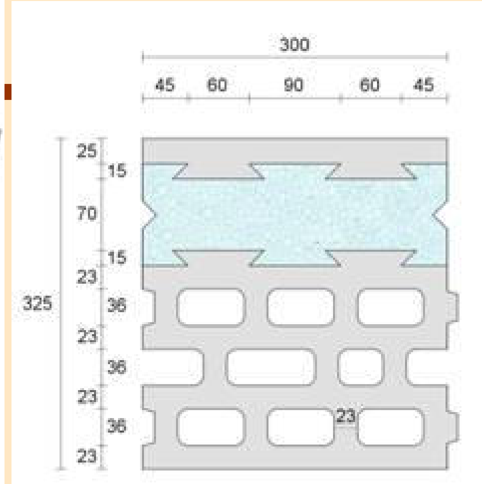
Energy Performance of Buildings and Local Energy Policy: the Case of New Residential Buildings in Greve in Chianti (Firenze)

The examined cases demonstrate the possibility to realize very low-energy-consumption buildings using quite simple building techniques. As regards the investigated cases, the ‘conductances’ values of the enveloping elements, both opaque and transparent, are sensibly lower than the maximum ones imposed by the national law for the climatic zone E. The different flats composing the two buildings examined are all characterized by very low values of energy to be delivered to the heating system for space heating (QR) and amount to 15÷40 kWh/m^{2}year (1.5÷4 gas-oil litres/m^{2}year). The energy to be delivered to the heating system for DHW production (QW) amounts to 15÷25 kWh/m^{2}year for all the examined cases.

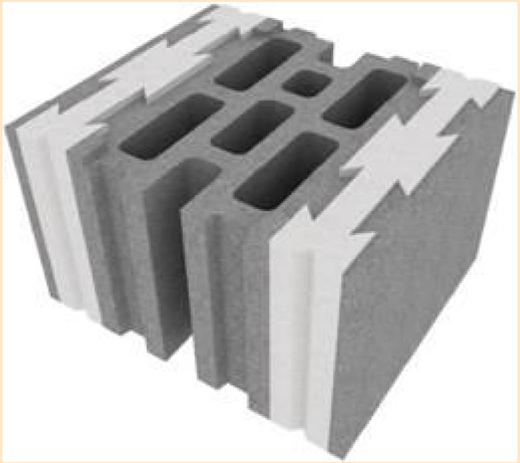


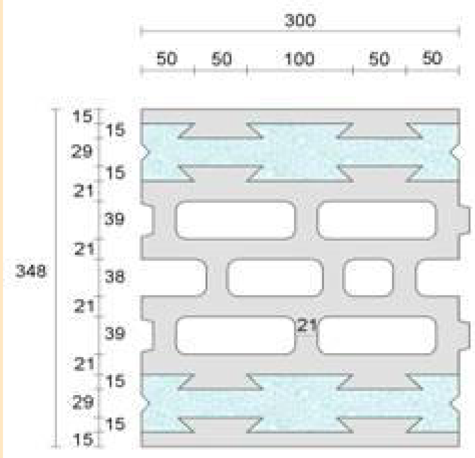


Energy Performance of Buildings and Local Energy Policy: the Case of New Residential Buildings in Greve in Chianti (Firenze)



Thermal insulation





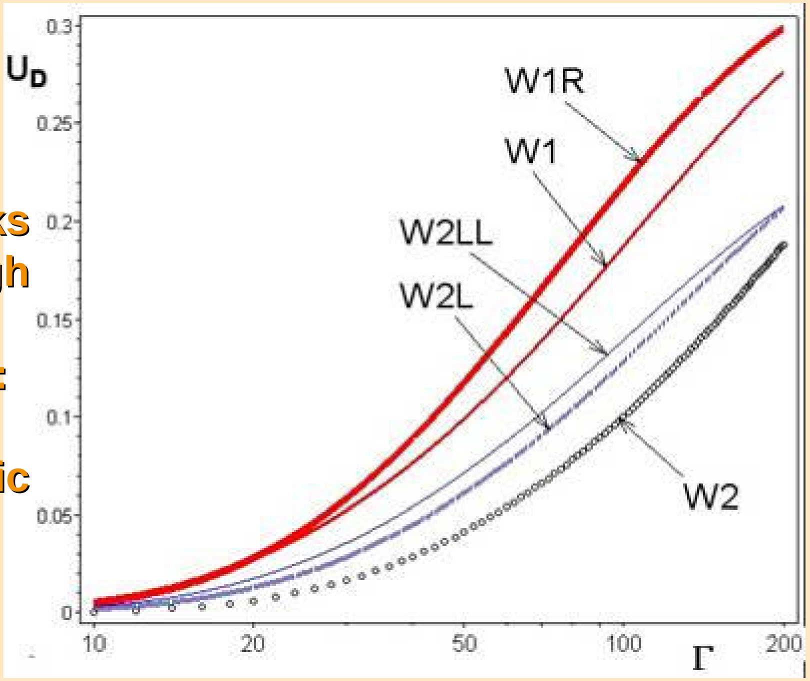
Vibro-compressed concrete hollow blocks with high thermal performance: steady-state and dynamic thermal behavior

The Building Physics Group has an ongoing research project aimed to the design of a new wall element able to satisfy the most recent legislation both in terms of mechanical and thermal performance. The thermal behavior of vibro-compressed concrete hollow blocks with one or more incorporated layers of thermal insulating material has been analyzed. The analysis of thermal resistance has been performed with the finite elements method, according to the EN 1745.

Table 2. Thermo-physical properties of the considered materials (EN ISO 10456/2007).

Material	ρ (kg/m³)	k (W/mK)	c_p (J/kgK)
Concrete A- Crushed stone concrete	2340	1.79	1000
Concrete B- Expanded clay concrete (wall WL)	1230	0.460	1000
Concrete C- Expanded clay concrete (wall WLL)	900	0.295	1000
Rigid panel in EPS	30	0,032	1450
Plaster in lime mortar	1800	0.90	1000
Insulating plaster	500	0.09	1000

Vibro-compressed concrete hollow blocks with high thermal performance: steady-state and dynamic thermal behavior



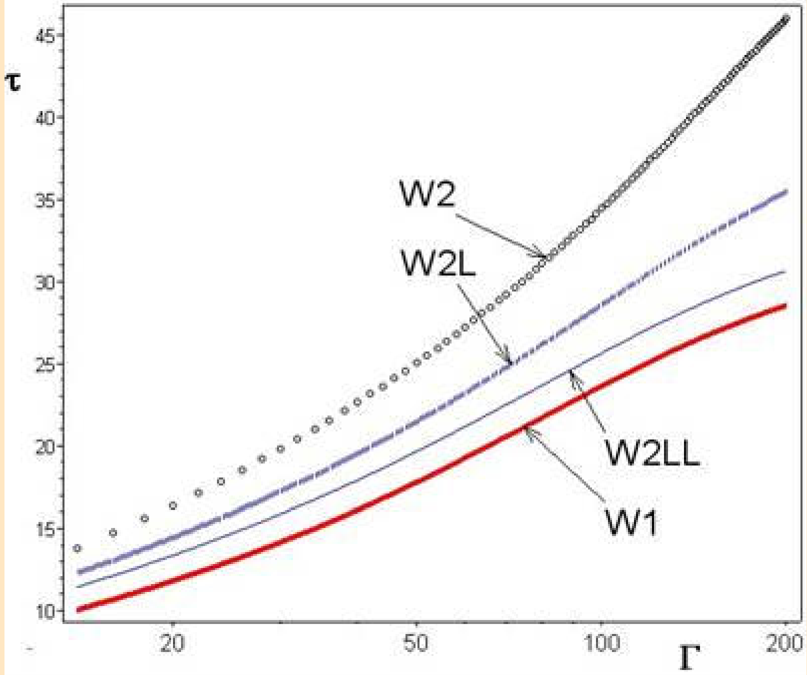


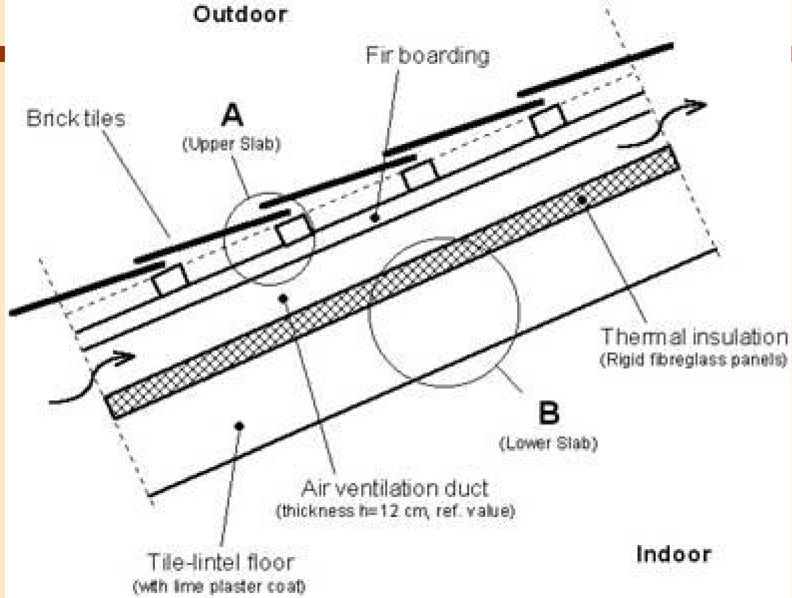
Table 3. Values of U (W/m²K) and ℜ (m²K/W) evaluated by using a finite elements method.

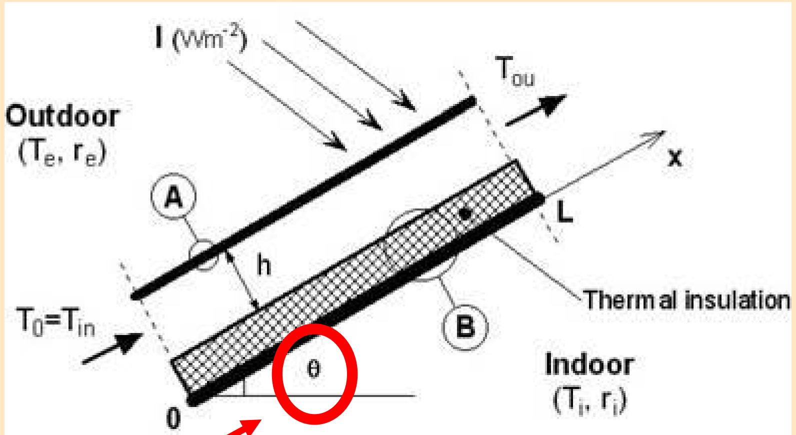
Walls		W1/W1R	W2	W2L	W2LL
with concrete blocks	U	0.348	0.347	0.287	0.264
with concrete blocks and insulating plaster	U	0.303	0.303	0.255	0.237
Blocks		**TM**	**TM2**	**TM2-L**	**TM2-LL**
only concrete blocks	ℜ	2.84	2.84	3.44	3.75

Table 4. Calculation results.

Wall	Block	M (kg/m²)	U (W/m²K)	C (kJ/kgK)	f	τ (h)	U_D (W/m²K)
W1	TM (external insulation)	393	0.348	457	0.107	12.82	0.0374
W1R	TM (internal insulation)	393	0.348	457	0.115	13.49	0.0399
W2	TM2	395	0.347	467	0.0290	17.88	0.0101
W2L	TM2-L	216	0.287	280	0.0659	15.64	0.0189
W2LL	TM2-LL	162	0.264	224	0.0937	14.44	0.0247

The walls, built with the analyzed blocks, are able to widely satisfy the limit values of thermal transmittance imposed by the national legislation. The thermal transient behavior of the examined walls has been studied with reference to the following parameters: decrement factor, time lag and dynamic thermal transmittance.





<u>In the last few years naturally ventilated walls (facades and roofs) have been widely investigated owing to the remarkable reduction in summer overheating due to solar radiation, achievable by using these structures.</u> Ventilated roofs (VR), if well designed, can improve thermal comfort level in the attics and can help to reduce summer thermal loads, in particular in moderate-height and wide-area buildings (e.g. small houses, industrial buildings). A recent European Directive on the energy efficiency in building (2002/91/CE) suggests developing passive cooling techniques in order to improve indoor climate quality as well as to decrease air temperature and air pollution in urban heat islands in summer.

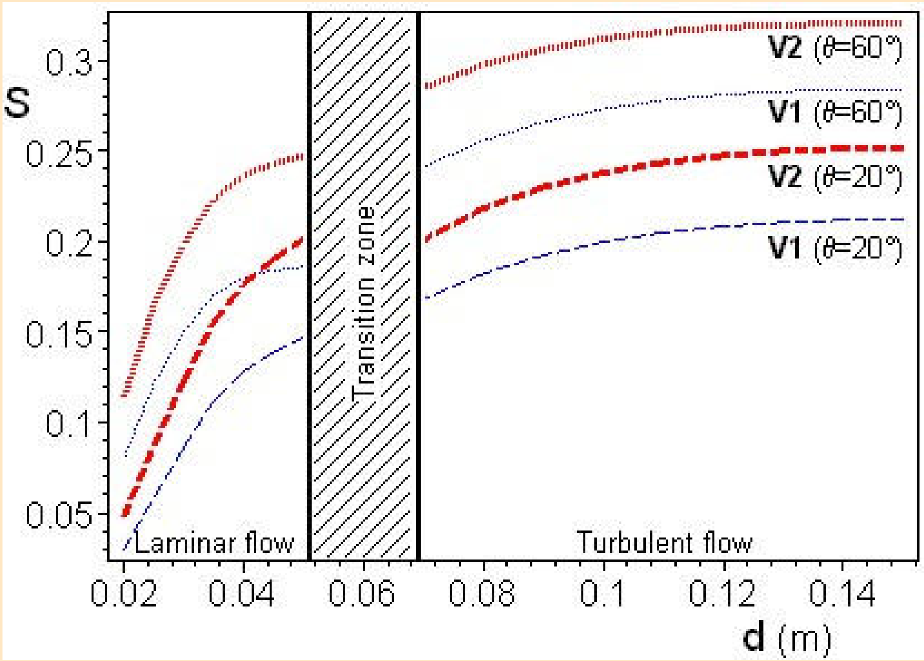
<u>A simple analytical method has been proposed by the Building Physics Group in order to estimate the energy performance of ventilated structures and to give some useful design guidelines.</u> In this work some peculiar VR have been investigated with respect to summer behaviour; the performance of brick-tile roofs, widely used in Italy, is compared with that of the metallic ones, widely used in contemporary architecture. The energy convenience of small-sized-thickness ventilated air ducts (microventilation) is also studied.

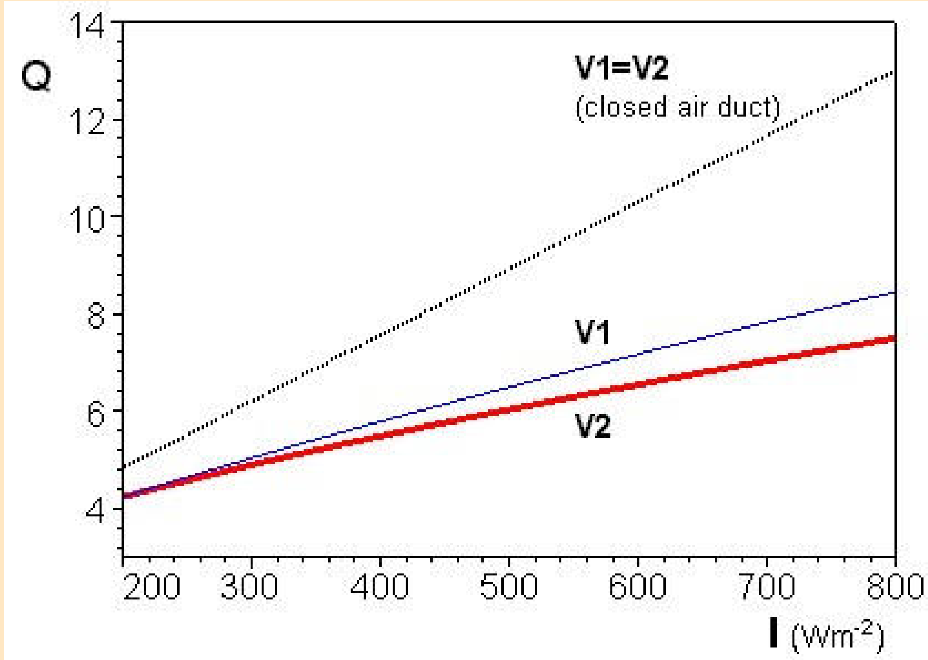
ENERGY ANALYSIS OF VENTILATED ROOFS IN SUMMER COOLING OF BUILDINGS

Ventilated roofs

ENERGY ANALYSIS OF VENTILATED ROOFS IN SUMMER COOLING OF BUILDINGS

	Number of layer	Description of layer		Thickness (m)	Density (kg m^{-3})	Thermal conductivity (Wm^{-1}K^{-1})
Roof V1	1 (Ext)	Upper slab (A)	Copper plates	0.0006	8900	380
	2		Polyethylene sheet	0.001	950	0.35
	3		Fir boarding	0.010	450	0.12
z_0=0.124	4	Air (ventilation duct)		(0.12)	-	-
R_A=0.0862 m^{2}KW^{-1} R_B=1.39 m^{2}KW^{-1}	5	Lower slab (B)	Rigid fibreglass panels	0.040	100	0.038
	6 (Int)		Fir boarding	0.040	450	0.12
Roof V2	1 (Ext)	Upper slab (A)	Brick tiles	0.025	2000	0.90
	2		Polyethylene sheet	0.001	950	0.35
	3		Fir boarding	0.040	450	0.12
z_0=0.270	4	Air (ventilation duct)		(0.12)	-	-
R_A=0.364 m^{2}KW^{-1} R_B=1.11 m^{2}KW^{-1}	5	Lower slab (B)	Rigid fibreglass panels	0.030	100	0.038
	6		Tile-lintel floor	0.180	1800	0.60
	7 (Int)		Lime plaster coat	0.015	1400	0.70

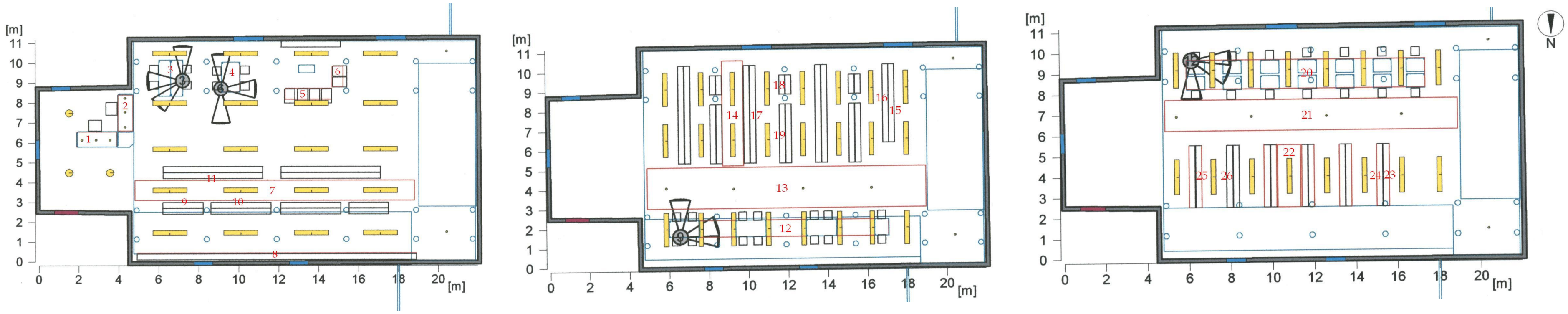




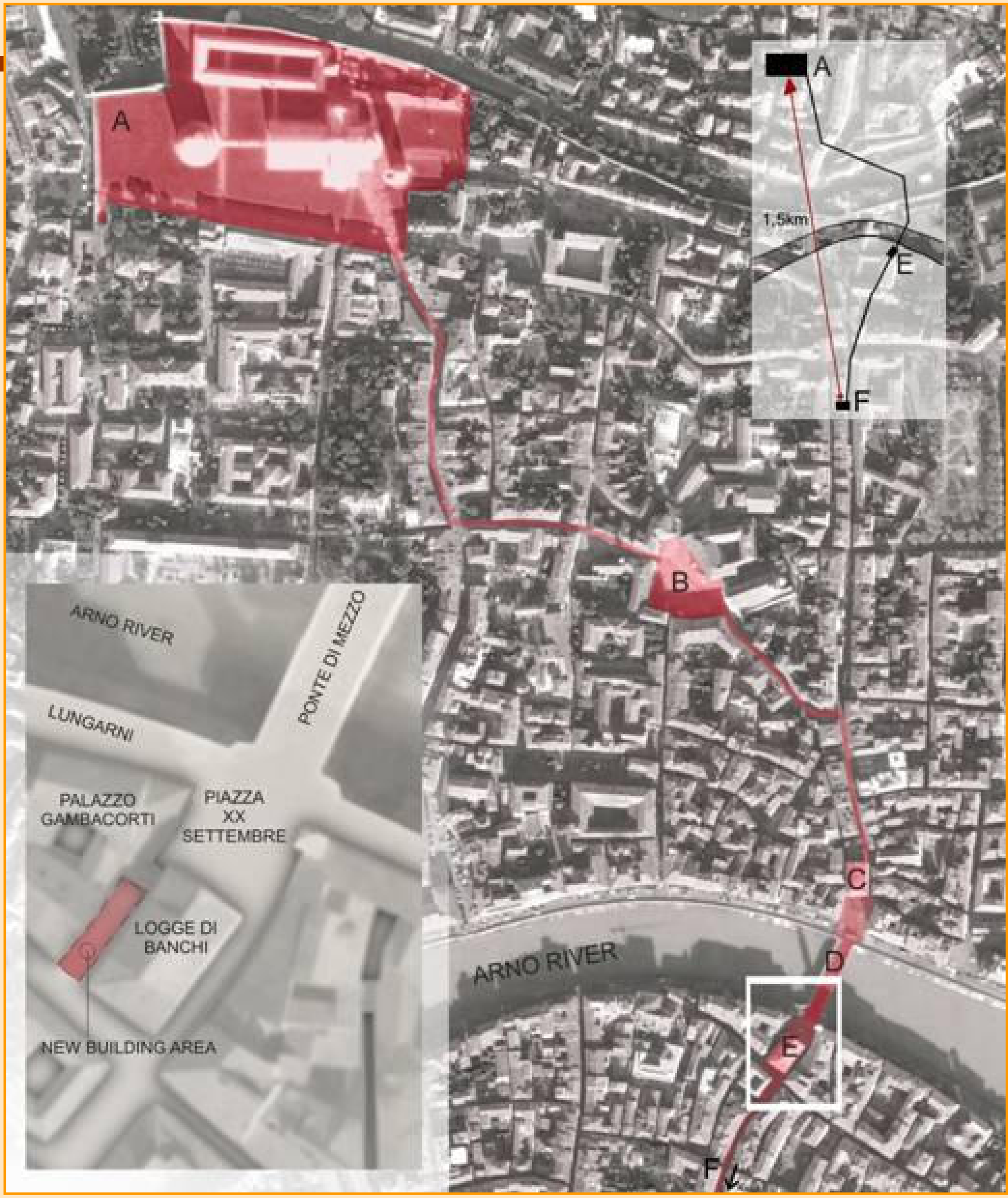
The recovery of old buildings out of use to be designed for services for which they were not designed for originally has become, in Italy, a widespread practice. The choice to reuse old buildings with strong architectural and monumental connotations, generally poses problems relating to structural adequacy, energy consumption control, functionall distribution of new spaces as well as to the satisfaction of indoor comfort parameters (i.e. the minimum lighting requirements).

In this example the preliminary plan of the new town library of Piombino (Livorno, Tuscany - Italy) (to realize in the ex-Church of S. Antimo - medieval age, c.1250) is illustrated. The results of an extensive analysis concerning day- and artificial lighting of the consultation and reading areas of the new library to be realized in the nave of the ex-Church are shown. Finally, the evaluation of energy demand for artificial lighting, by calculation of Lighting Energy Numeric Indicator (LENI), is presented.

Daylighting and Lighting Energy Demand Analysis of the New Town Library of Piombino (Italy)



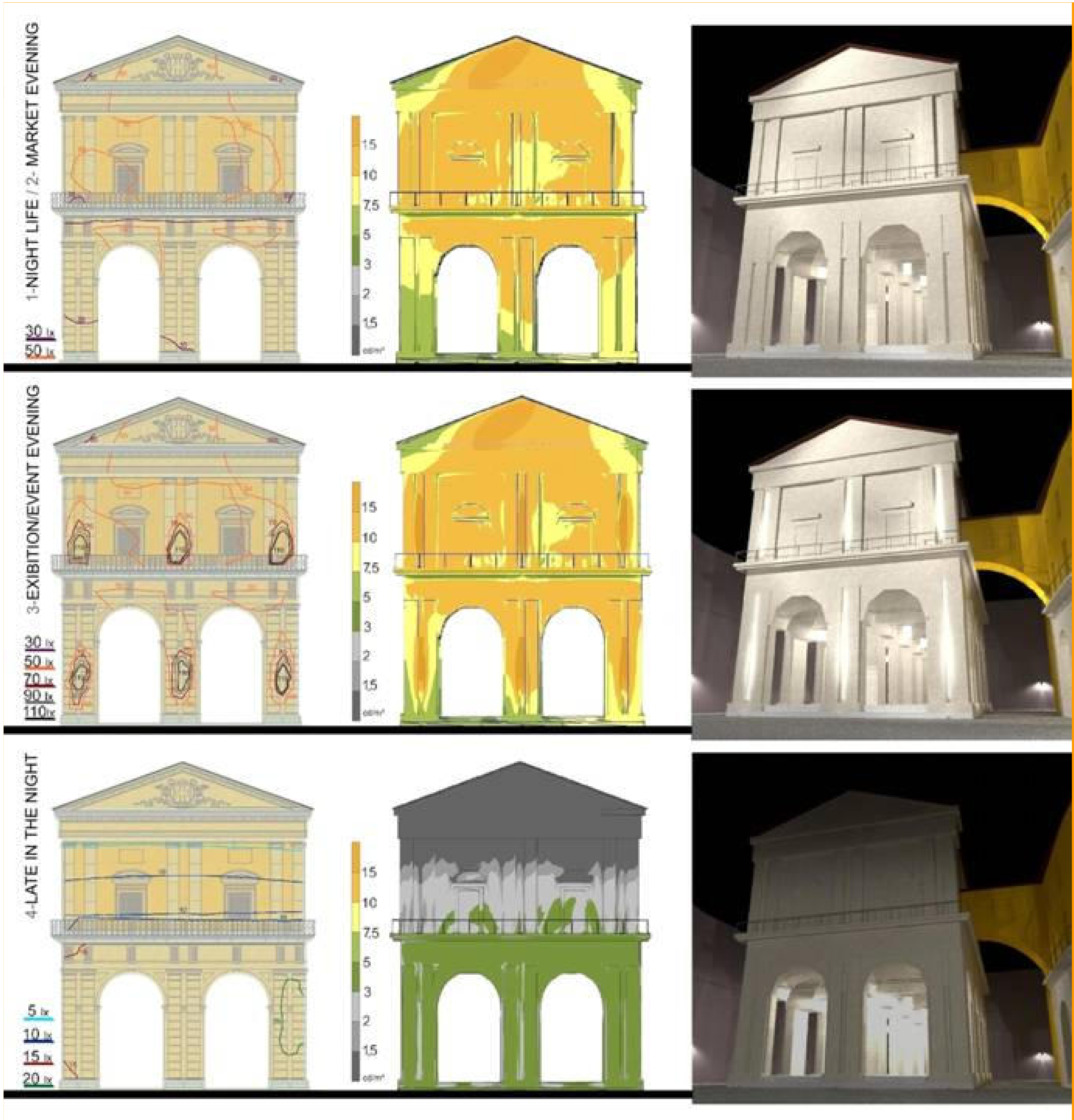
Daylighting and Lighting Energy Demand Analysis of the New Town Library of Piombino (Italy)



Architectural lighting of the seventeenth-century building “Logge di Banchi” (Pisa) for the retraining of the pedestrian axis Leaning Tower–Railway Station

<u>The revitalization of the historical centres of many</u> small-dimension and mean-dimension <u>Italian towns has been carried out in the last few years by a careful study of lighting</u>.
The case of Pisa:
the pedestrian route connecting the railway station (F) with the Miracles Square (A) through Ponte di Mezzo (D) on the Arno river and medieval square of Cavalieri (B).
This route is characterized by many shops and restaurants with a strong night appeal. A key point of the route is the Ponte di Mezzo surrounded by important historical buildings.

Architectural lighting



Architectural lighting of the seventeenth-century building "Logge di Banchi" (Pisa) for the retraining of the pedestrian axis Leaning Tower–Railway Station

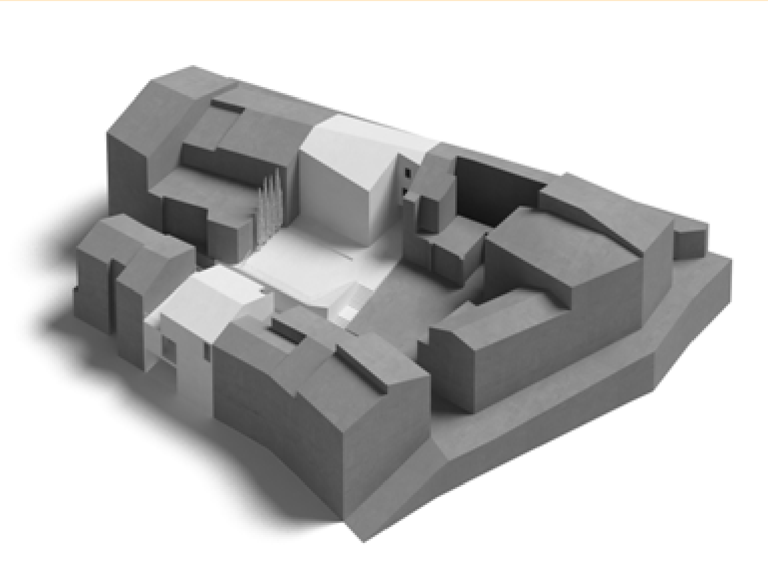
Fig. 1 - Pisa (Italy) town centre, night views of the urban scene: Lungarno Galilei (above) and Ponte di Mezzo (below).

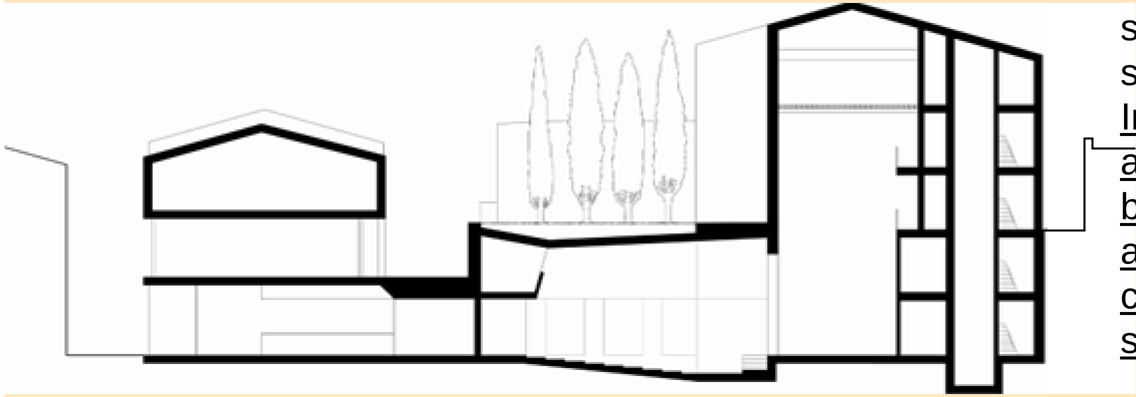
The lighting of urban areas, in particular Italian historic town centres, has been representing, in the last decade, a response to the use of the urban spaces and their historic and architectonic heritage as well as to the ever-growing demand for safety in the night-time. The lighting has become an element of urban and environmental renovation being able to define the town night view and to create suggestive atmospheres and peculiar scenographic effects.

The Building Physics Group wish to investigate the night view comfort requirements by examining the most important lighting parameters and to provide an updated outline of the legislative acts and technical standards on this topic, with particular reference to the state of the art in Italy.

LIGHTING REQUIREMENTS AND OTHER ENERGY AND SAFETY ASPECTS IN URBAN AREAS

Analysis of Acoustic Requirements of a Small Hall of a Theatre According to the Coupling Factor with the Stage Tower





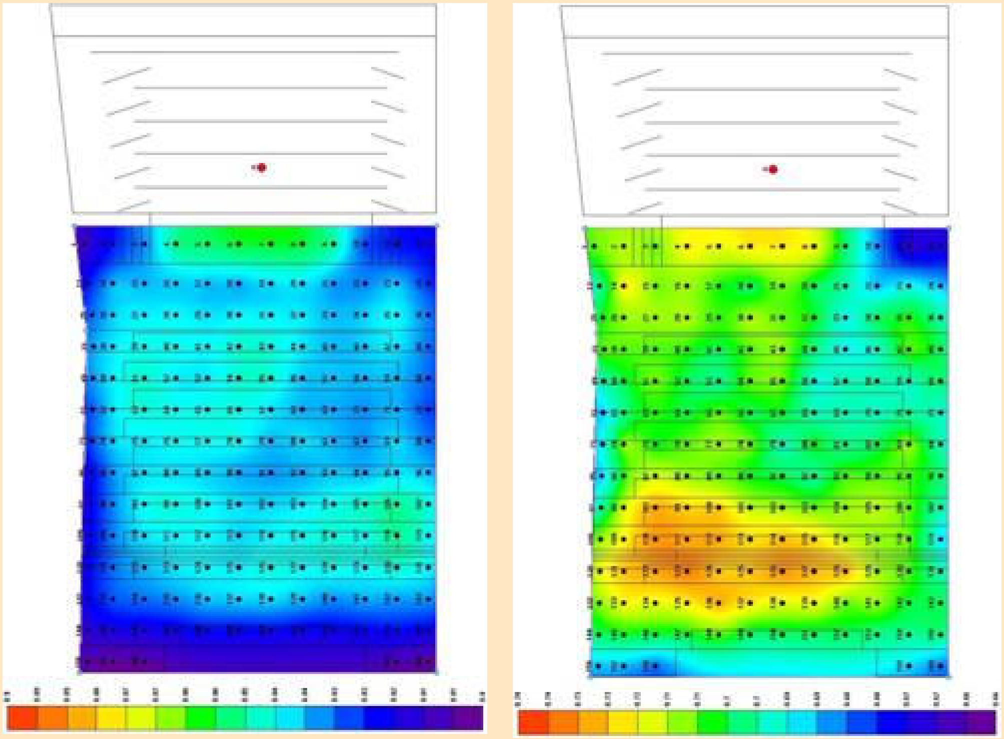
In recent years in Italy, the renovation or construction of public buildings, especially auditoriums (for music) and theaters (for prose and the lyric) has become a widespread practice in urban restoration of small and medium-sized towns.

The most pervasive tendency in contemporary architectural design of auditoriums and theaters is to realize one-space hall without galleries or balconies, with an accurate furniture design.

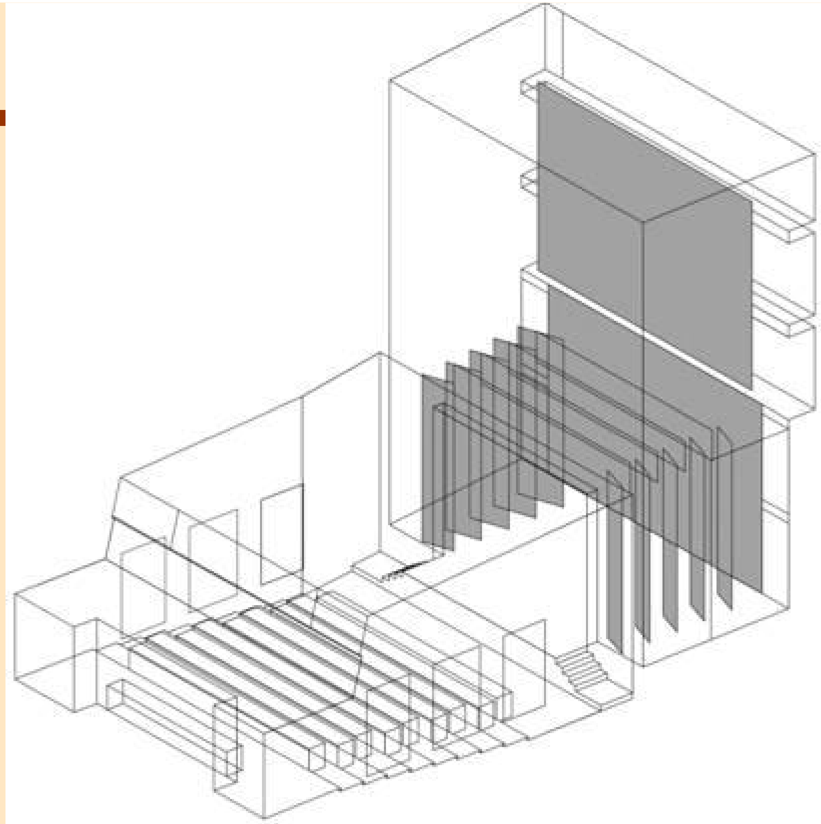
In the case of theaters, the size of the stage tower is comparable to the one of the audience hall and it has an equivalent absorption area similar to the hall one, depending on the scenes equipments in the stage tower.

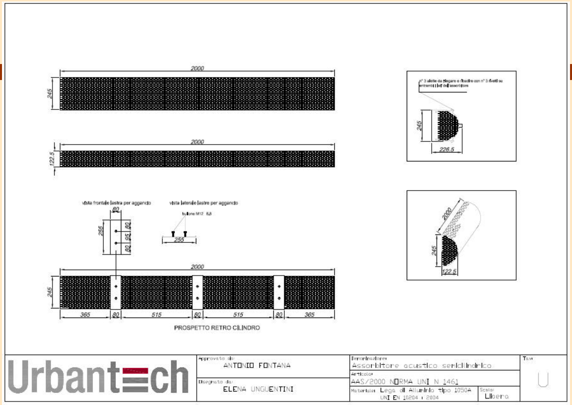
In this study the results of the analysis of acoustic requirements of a small theatre hall built in San Miniato (Tuscany, Italy) are shown and discussed. The analysis has been conducted using the acoustic simulation software RAMSETE.

Analysis of Acoustic Requirements of a Small Hall of a Theatre According to the Coupling Factor with the Stage Tower



Reverberation time (500 Hz and 1000 Hz)

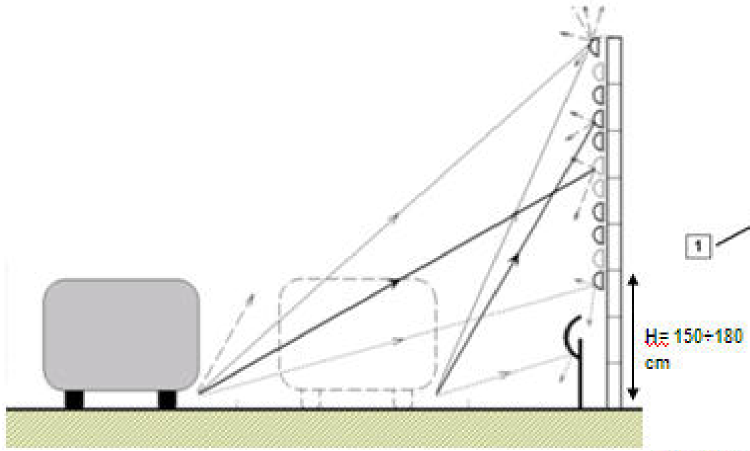




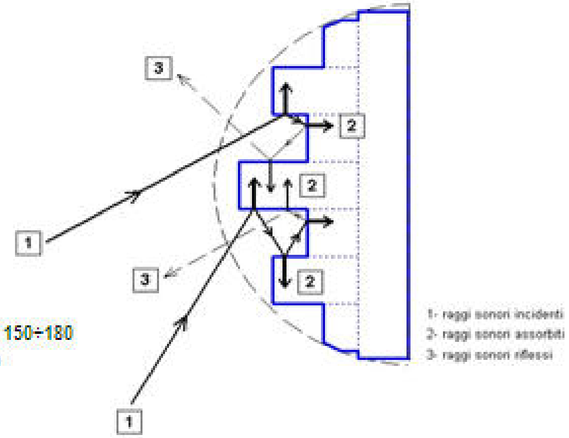
The need to enhance the people's mobility has produced a significant increase in the environmental pollution, including transportation noise. In order to reduce transportation noise it is possible to act directly on transport media or on the urban environment, by protecting sensitive receptors with techniques for noise reduction. **The noise barriers are one of the most common examples of noise reduction devices.**

In this paper the authors show and discuss the results of an in situ analysis of the acoustical performance of concrete noise barriers, installed in an important highway infrastructure of the Central Italy. The structure of examined barriers is composed of 8 overlapping panels made by autoclaved aerated concrete. The faces of the panels, facing the noise source, can be smooth or machined with high pressure water jets. In order to increase the sound absorption of the barriers, till to the higher quality class (A4) indicated in EN 1793-5, semi-cylindrical acoustical absorbers have been designed. They are made by metallic micro-holed envelope with the cavity partially filled by suitably shaped polyester fiber (or also with recycled materials) and they can be installed at variable distances from the face of the panel.

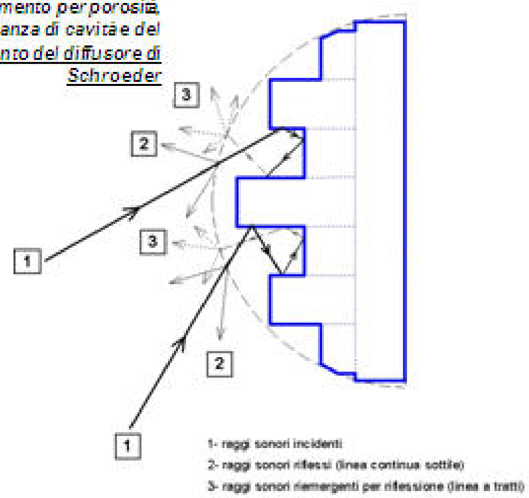
Analysis of in Situ Acoustical Performance of Concrete Noise Barriers

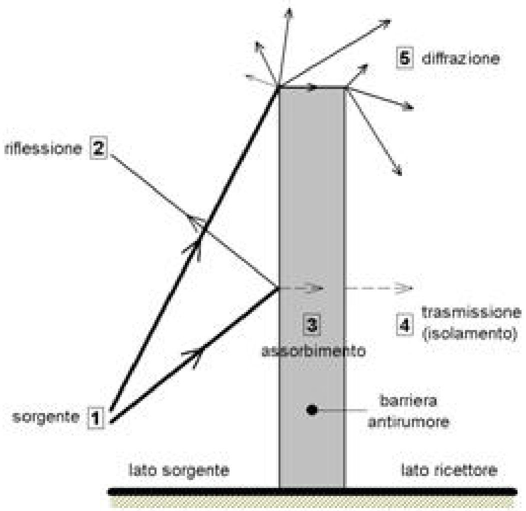


Esemplificazione in sede stradale dei fenomeni di diffusione e diffrazione della barriera antirumore con gli assorbitori semicilindrici installati: <u>DETERMINAZIONE DELL'ALTEZZA A PARTIRE DALLA QUALE RISULTA EFFICACE LA FONOASSORBENZA</u>

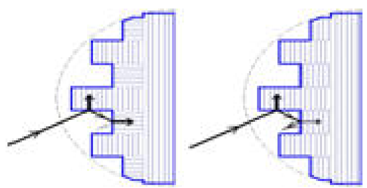


Esemplificazione dell'assorbimento per porosità, per risonanza di cavità e del <u>funzionamento del diffusore di Schroeder</u>





Schema esemplificativo delle <u>caratteristiche acustiche di una generica barriera antirumore</u>

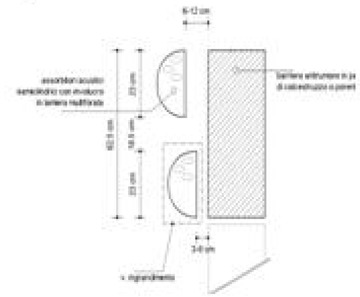


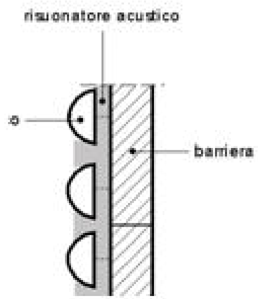
Miglioramento dell'assorbimento acustico del sistema in relazione alla giacitura delle fibre del materiale fonoassorbente

VANTAGGI ACUSTICI DIPENDENTI DALL'INSTALLAZIONE SFALSATA DELL'ASSORBITORE RISPETTO ALLA BARRIERA

Assorbimento per porosità sulla faccia piana posteriore dell'assorbitore e per risonanza di cavità relativa al tipo di installazione distanziata

Riduzione dei fenomeni di diffrazione sul bordo superiore grazie anche all'elevato spessore





Miglioramento dell'assorbimento acustico per porosità

Assorbimento per risonanza di cavità

Acoustical in situ measurements


A1 FIRENZE
60


60

Thank you for attention …

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