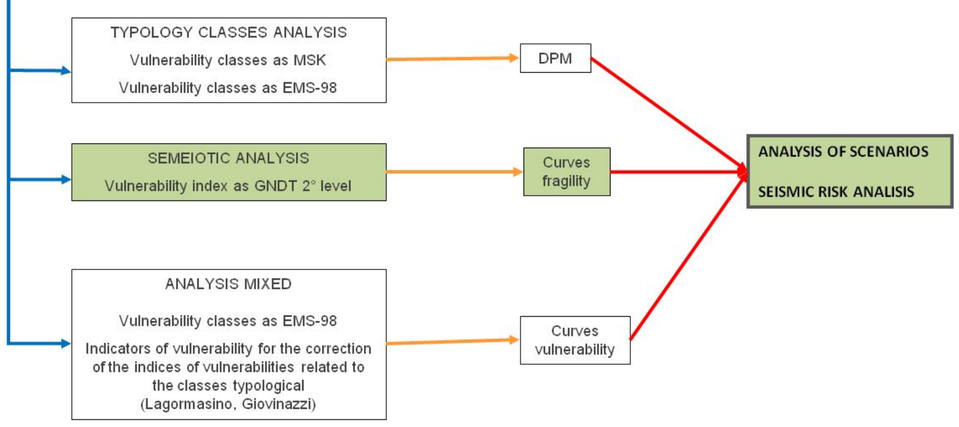
National Research Council
Construction Technologies Institute
Office L'Aquila- Italy

METHODOLOGY FOR EVALUATING THE SEISMIC VULNERABILITY OF BUILDINGS AND THE DEFINITION OF RISK SCENARIOS IN URBAN AREAS

G.Cifani, G.Cialone, L.Corazza, A.Martinelli, A.Mannella, L.Milano, A.Petracca, G.Petrucci

The evaluation of building vulnerability is an essential part of any project looking at seismic risk on an urban scale. Hence of equal importance is the level of investigation which will give the results required within acceptable limits of time and cost. Varying procedures for the evaluation of building vulnerability have been devised to provide differing levels of information on the basis of the dimension and object of the study. Problems linked to seismic risk and policies aimed at reducing this risk must be studied with an overall perspective that takes into account: forecasting, damage prevention, emergencies and reconstruction which are interlinked. Everything that takes place in one phase is conditioned by what took place in the previous phase and will influence all of the following phases. Differing instruments and evaluation methods have been created for analyzing risk on a territorial scale in Italy, based on building type (level I analyses) or on factors conditioning building behaviour during an earthquake (level II analyses). Research aimed at reducing seismic risk, creating damage scenarios for urban planning and dealing with post-seismic emergencies requires more detailed information on seismic vulnerability than that provided by level I analyses. The study carried out by the ITC-CNR- L'Aquila focused on the historical centre of Sulmona. All of the buildings in the historical centre (approximately 1300) were evaluated using a brief form system. The data collected and the analyses performed are given on the right. The vulnerability of ordinary buildings was evaluated in order to construct damage scenarios for hypothetical macroseismic intensities. Damage is expressed as a percentage of the value of a new building.

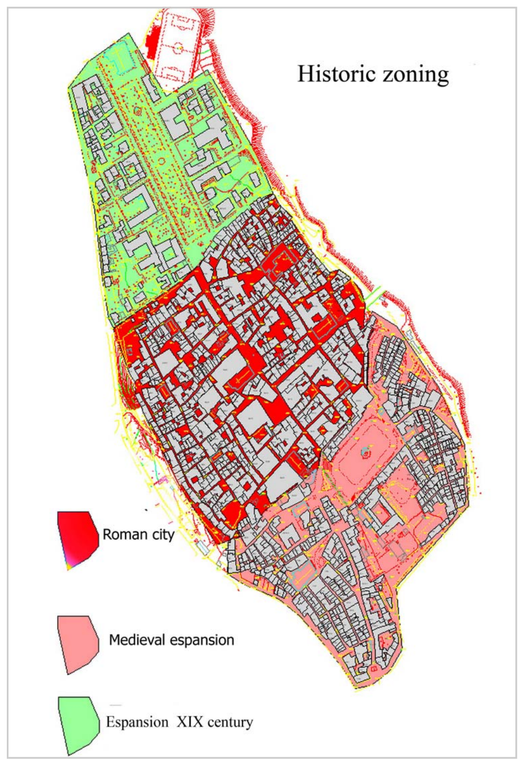
Fast method for the evaluation of building vulnerability



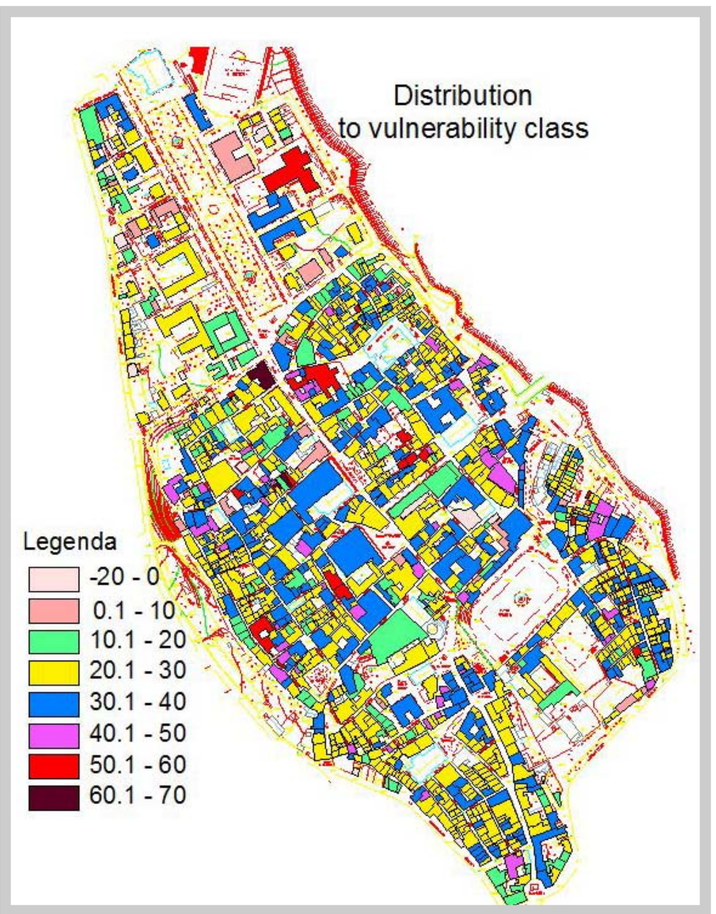
LIST OF DATA CONCERNING MASONRY BUILDINGS

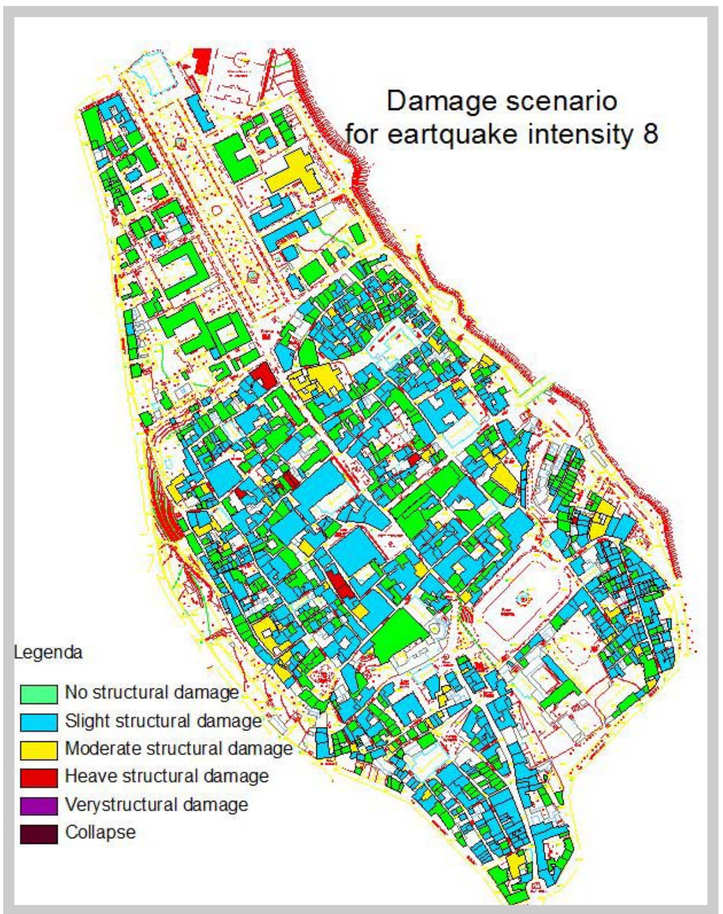
1 General data	2 Type data	3 Construction data	4 State	5 Results
Aggregated type	Structural typology	Roof geometry	External plastering	Vulnerability index
Morphology of the site	Vertical structure typology	Joining of vertical structures	State of conservation	Collapse mechanism
Instability	Horizontal structure typology	Joining of horizontal structures	Amount of use	PGA
Total no. of floors	Covering structure typology	Regularity	Type of use	Damage to earthquake intensity = 7
No. of floors above ground		Reinforcing elements		Damage to earthquake intensity = 8
Area		Openings in the facade		Damage to earthquake intensity = 9
Average floor surface area		Weakest floor		Damage to earthquake intensity =10
Average inter-floor height		Non-structural elements		MSK vulnerability class
Highest inter-floor height				
Maximum height of the building				
Minimum height of the building				
Age				
Work				

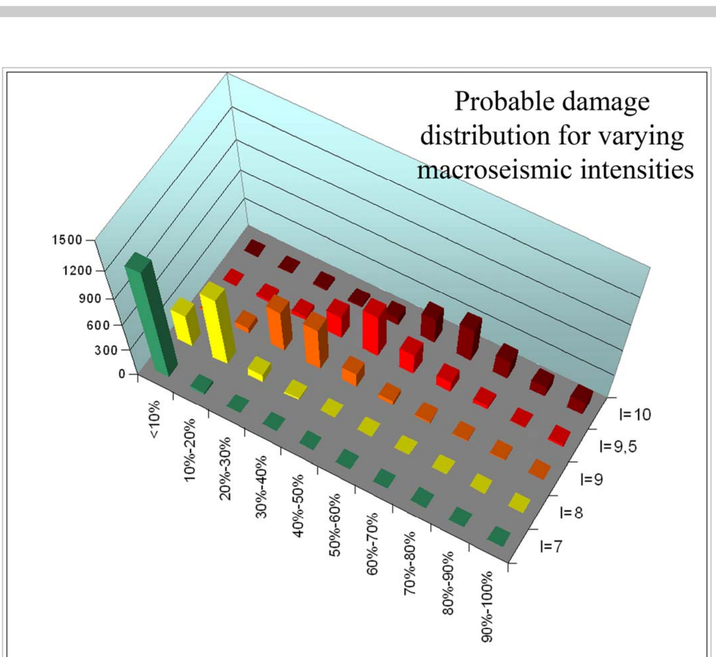
SULMONA
(Italy)
Historical centre



Ordinary buildings



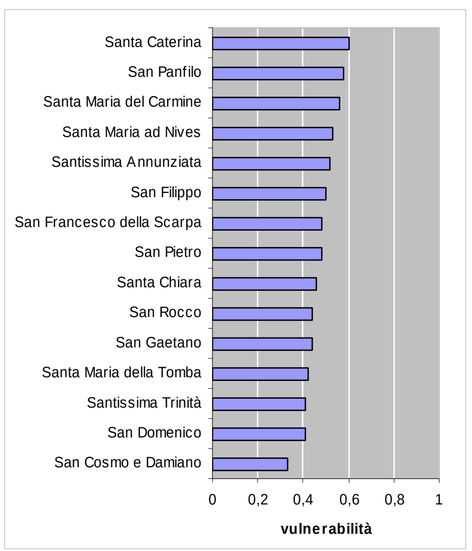




	<10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
I=7	1206	28	0	0	0	0	0	0	0	0
I=8	364	758	88	18	6	0	0	0	0	0
I=9	20	56	457	469	156	41	18	9	6	2
I=9,5	2	26	43	255	469	231	119	47	14	28
I=10	0	8	20	22	75	274	366	204	117	148

Religious buildings

Special buildings within the historical centre, such as churches, were given particular attention as they are notoriously more vulnerable than current buildings and their position often gives rise to a higher risk for surrounding buildings and the transport system. The vulnerability of churches was assessed using the Church Form which has been used on various occasions and in particular for the recording of seismic damage caused by the Umbria-Marche earthquake in 1997. The vulnerability indexes of the 15 churches within the centre were evaluated using the associated procedure "the 28 mechanism church form".



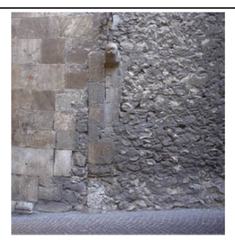
PROJECT S.I.S.M.A
System Integrated Security Management Activities

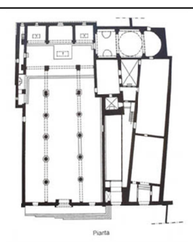
Church of Santa Maria della Tomba

Description of the the building complex : The first news of the church have in the century. XIII: in 1225 and more extensively in 1241. The original church was three aisles, with coverage trusses, not very large, but the expansion fourteenth century the city made an indispensable extension of the premises, executed in 1400. Its name derives from the fact that would be built on the ruins of a pagan temple dedicated to Jupiter. It presents a facade palace in the Romanesque style, a late Gothic portal of 1441 by that Jacobu and a large rose window of 1400, the work of Palma de Amabile. It was devastated by earthquakes in 1455-61. Beside the church, in 1424, was erected a hospital of which today remains only the facade with a mullioned window. The bell square with clock was built in 1479. The interior is divided into three naves and topped by a ceiling truss wooden supported by six pillars cylindrical. Among the most important furnishings are a fine Madonna and Child terracotta school Abruzzo late'400, a bell dated 1314 and belonged to the church of St. Lucia, parietal frescoes and paintings on canvas XVI-XVIII century. The last restoration dates back to 1970-71 when it was restored to its medieval, removing all traces of Baroque.

PHOTOS

Vulnerability indicators identified : Presence of large openings in the top of the facade (rosette): mechanism activated M2; Steady presence of considerable size and times sheet with spans of great light (times of chapels): mechanism activated M24; irregularities plane in elevation: mechanism activated M25; presence of openings on several levels: mechanism activated M27; presence of heavy coverage and push coverage in the belfry: mechanism activated M28





Plan type : **three naves**
Position of church: **urban context**
Use: **daily**
Internal surface area : **mq.836**
State of conservation: **good**

Central nave length Lu : **mt. 32,3**
Central nave width La: **mt. 7,9**
Area covered: **mq.1100**
Vulnerability:.**0,42**
Activation mechanisms :***M2- M24- M25- M27- M28***

PROJECT S.I.S.M.A
System Integrated Security Management Activities

Church of Santissima Annunziata

Description of the the building complex: the church was founded in 1320 by the secular brotherhood Compenitenti di Sulmona; a hospital for invalids and the pupils of a music school was adjoined to the church. The building was completely destroyed in the earthquake of 1456. Rebuilt at the beginning of the 1500s, the church was destroyed once again by the earthquake in 1706. It was subsequently rebuilt in 1710 by the architect Pietro Fantoni who did not alter the original design. The interior is divided into three naves and decorated with affrescos by Giambattista Gamba and stuccos. There is also a wooden chancel by the Sulmonese Bartolomeo Balcone (circa 1570), a stand in wood for the baroque organ attributed to Ferdinando Mosca, canvasses and furniture from the 1600s. The Church houses the body of the Sulmonese Panfilo Serafini. The architecture of the entrance suggests Spanish or Portughese gothic origins. The triforium in the facade is typical of the first Renaissance. The bell tower, at 65.5 metres, is the highest building in the city and was designed by the Napolitan Matteo Colli. Inside there are the remains of Roman buildings, mosaic floors and wall affrescos dating back to 1 A.D.

PHOTOS

Vulnerability indicators identified: the presence of thrust elements (covering struts, vaults, arches), the presence of large openings in the lateral walls near the corners: activation mechanism M1; the presence of large openings at the top of the facade (rose windows): activation mechanism M2; irregularities in the vertical planes; activation mechanism M25; presence of openings on several levels: activation mechanism M27; presence of heavy coverage and coverage spingente in the belfry:activation mechanism M28.

Plan type : **three naves**
Position of church: **urban context**
Use: **occasional**
Internal surface area : **mq.569**
State of conservation: **good**

Central nave length Lu : **mt. 31,6**
Central nave width La: **mt. 7,4**
Area covered: **mq.650**
Vulnerability:.**0,52**
Activation mechanisms:**M1- M2- M9- M16- M25- M27- M28**