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Building Inventory at National scale by evaluation of seismic vulnerability classes distribution based on Census data analysis: BINC procedure

Francesco Cacace*, Giulio Zuccaro, Daniela De Gregorio, Francesca Linda Perelli

PLINIVS Study Centre for Hydrogeologic, Volcanic and Seismic Engineering University of Naples Federico II, Naples, Italy

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ABSTRACT

In this paper, the BINC procedure (Building Inventory at National scale based on Census data) is proposed. It is a quick methodology to assess the building inventory needed to seismic exposure assessment at regional and national scale. Vulnerability classes map for the whole Italian region is proposed.

BINC procedure, developed at the PLINIVS Study Centre (University of Naples Federico II), is able to provide a seismic vulnerability assessment on the basis of 'weak' data. The information used to set the method are carried out from census database furnished by Italian National Institute of Statistics, ISTAT (DB_Census) and the database of information collected in situ by PLINIVS (DB_PLINIVS). In particular, exploiting vulnerability classes information of the DB_PLINIVS and common characteristics of the two databases, a generalization of buildings distribution on the vulnerability classes in obtained at regional national scale.

The methodology can be easily extended to all countries having census data on buildings.

1. Introduction

In the framework of planning and management of seismic emergency at national and regional scale, the analysis of scenario and risk constitutes the main tools to define the mitigation strategies at short and long term, to allocate the available resource and to device the operative phases in the emergency.

The risk is the convolution of three factors: hazard, exposure and vulnerability. The hazard is the time-space distribution of the intensity of a given seismic event of assigned occurrence probability in a given time and a given geographical area. The exposure is the distribution of the probability that a given element (people, building, infrastructure, economy, environment, etc.) of assigned characteristics (of qualitative and quantitative type) occupies in a given time and a given geographical area. The vulnerability is the distribution of the probability that a given exposed element of assigned characteristics is damaged by seismic hazard.

In this paper an approach to assess the building inventory (exposure) at national and regional scale is proposed. It is called BINC procedure (Building Inventory at National scale based on Census data) and it is developed by the authors in the framework of PLINIVS Study Centre research activities. For each Italian municipality, it aims to identify, the distribution of vulnerability classes (which represent buildings sets characterized by similar behavior under effect of seismic hazard) on the base of Italian census data [1].

Seismic exposure assessment finalized to risk assessment requires a specific approach, since it involves large numbers of buildings. In literature, different procedures able to assess the building inventory in the framework of risk assessment exist. The maim methods are of two kinds.

The former provides the development of global database of building inventories using taxonomy of global or national building types for use in near-real-time post-earthquake loss estimation and pre-earthquake risk analysis, as: Russian program Extremum [2], HAZUS-MH [3], PAGER [4], GEM [5], CARTIS DB [6]. These data base are generally completed by inside and outside building-by-building analyses by expert teams, so they may provide high quality vulnerability information, but, given the onerousness of the activities in the field, they often do not cover the entire regional or national territory, so these data base must be completed on the base of information at large scale, as census

Abbreviation: C_{ij}, Alternative option j of the parameter combination i; I_c, comparison index; N_b, Number of buildings in reference to DB_PLINIVS; M_b, Number of buildings in reference to DB_Census; P_{ij}, Alternative option j of parameter i; BINC, Building Inventory at National scale based on Census data; DB_Census, ISTAT 2001 database on buildings, with aggregated data (8101 municipalities); DB_Census1, ISTAT 2001 database on buildings, with not aggregated data (190 municipalities); DB_PLINIVS, PLINIVS database on buildings (800 municipalities); DB_PLINIVS1, PLINIVS database on buildings (with reference to the same municipalities in DB_Census1); DB_PLINIVS2, PLINIVS database on buildings (610 municipalities); DPM, Damage Percentage Matrix; VC_k, Vulnerability Class; SAVE, Strumenti Aggiornati per la Vulnerabilità sismica del patrimonio Edilizio e dei sistemi urbani; SPD, Synthetic Parameter of Damage

* Corresponding author.
E-mail address: cacace@unina.it (F. Cacace).

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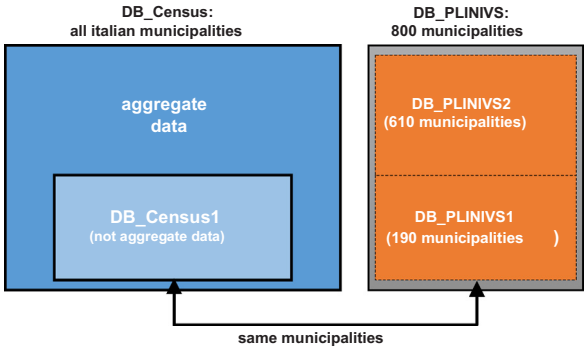

Fig. 1. Database used in the procedure.

data.

The latter proposes the satellite remote sensing to assess the buildings inventory, through the visual assessment by images of features that can influence the seismic performance of structures. These techniques can be founded on: pure satellite remote sensing (see [7–11]), providing information about vulnerability-related features that can be assessed from the top view; or integrated approaches, which combine satellite images and ground-based omnidirectional imaging data (see [12–15]). Differently from the approaches of the first type, they can quickly gather a lot of data at national and regional level, moreover they are able to better control the dynamic change over short time-scales (a few years) of urban settlements. On the other hand, they present the difficulty of evaluating the correlations between the data obtained from the images and the seismic vulnerability.

Probably, the most reliable exposure estimates should be assessed through hybrid approaches that seek to balance the pros and cons of the two families of methodologies.

The procedure here illustrated is included among the first methods. It is founded on the analysis of statistical correlations existing between 'weak' data available at national scale (see [1]) and more reliable data collected in site, on about 800 Italian municipalities (DB_PLINIVS), through survey activities building-by-building of structural- typological characteristics.

The study is founded on the numerous research activities developed in Italy in the framework of seismic risk assessment (see [16–40]).

The advantage of the procedure is to furnish a methodology easy to apply, based on 'weak' and 'free' data, striking a balance between the need of reliable data and the impossibility to get detailed surveys for all the buildings of a whole region or a whole country. The goal of the proposed inventory analysis is to assess, for each of the 8101 Municipalities of Italy, the number of buildings and their distribution in vulnerability classes according to the European Macroseismic Scale (EMS'98) vulnerability classification [41].

The methodology can be easily extended to all countries having census data on buildings, assessing statistical correlation with ad hoc information collected on the territory.

2. The methodology

The proposed procedure allows to estimate the vulnerability classes distributions (exposure) at regional and national level, starting from 'weak' data National Census data provided by ISTAT (Italian National Institute of Statistics).

The procedure deduces information about Italian Territory from the following databases (DB), shown in Fig. 1:

1. ISTAT 2001 database (DB_Census), at national scale, which contains for each minimum reference unit (identified by sub- municipal zones, called *census areas*), 'aggregate data', that is it furnish the number of buildings having a given single characteristic (i.e., building position in the aggregate, material of vertical structure, age of buildings, etc.) for each census area;
2. PLINIVS survey database (DB_PLINIVS), at local scale, in which georeferenced data relating to buildings typologies and vulnerability class are collected [42]. It is constituted by 800 municipalities and about 180,000 buildings.

Furthermore, thanks to the Italian Civil Protection, PLINIVS Study Centre has other special information collected by ISTAT, generally not free available, constituted by 'not aggregate data' (for information type) for 190 Municipalities (DB_Census1). These information furnishes, for each census area in the 190 municipalities, the number of buildings having a given combination of different characteristics.

The procedure proposed divides the DB_PLINIVS in two sets: the former one (DB_PLINIVS1) is constituted by the 190 municipalities in common with 'not aggregate data' DB_Census1; the latter one DB_PLINIVS2 is constituted by the rest of the 610 municipalities.

DB_Census provides typological buildings characteristics belonging to Census Area in which Italian country is divided, whilst DB_PLINIVS, through the SAVE Method [42], defines vulnerability classes over typological features of buildings belonging to 800 Municipalities. By exploiting common characteristics of two databases and the stochastic valence of the PLINIVS'one, a projection of buildings distribution on vulnerability classes is obtained at national and regional scale.

The common descriptive characteristics of the two databases are essentially six: building position in the aggregate, material of vertical structure, age of buildings, number of floors above ground, altimetry and demographic class. Each one of these characteristics is assumed as 'parameter' of the procedure and is partitioned by using alternative options (Table 1).

The procedure proposes the definition of expected buildings distribution for each parameter taken individually and for some combination parameters. In both of the cases, statistical analysis of the relations between the parameters and the vulnerability classes of the surveyed buildings (DB_PLINIVS) is studied. As appropriate, the

Table 1
Parameters of buildings.

		Parameters					
		P_1 position of the building in the aggregate	P_2 material of vertical structures	P_3 age of building	P_4 number of floors above ground	P_5 altimetry of municipality	P_6 demographic class of the municipality
Alternative options	**1**	Isolated	masonry	before 1919	1–2	plain (0–300 m)	< 500
	2	on one side	reinforced concrete	1919–1945	3–4	hill (300–600 m)	500–1.999
	3	on two or more side	rc with pilotis at ground level	1946–1961	5 – 6	mountain (> 600 m)	2.000–4.999
	4		other	1962–1971	7 – 8		5.000–9.999
	5			1972–1981			10.000–49.999
	6			1982–1991			50.000–249.999
	7			after 1999			> 250.000