Typological Inventory of Residential Reinforced Concrete Buildings for the City of Potenza

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Abstract. The seismic vulnerability assessment of the built heritage located on a specific area represents an important starting point for both the evaluation of the consequences in the aftermath of significant seismic events and a proper management of the post-seismic reconstruction phase. In other words, the vulnerability assessment represents one of the main input elements for resilience analysis at urban scale. However, facing with a large-scale study, a building-specific assessment approach appears extremely difficult and time-consuming. In this optic, the definition of territorial-specific structural typologies and corresponding vulnerability classes represent a powerful tool for a rapid estimation of the "global vulnerability" of an examined area. As a matter of fact, the classification of the built heritage in a limited number of structural typologies (featuring similar characteristics) could sensibly reduce the complexity of the vulnerability assessment, hence resilience analysis, at urban scale.

In this paper, an investigation on the built heritage of the city centre of Potenza (south of Italy) is proposed. In particular, the main typological and structural features of the residential Reinforced Concrete (RC) constructions, detected in the investigated territory, have been identified through an integrated approach involving: Census data, documentary analyses, site and virtual inspections (i.e. GIS-based analysis). The typological-structural characterization represents the first step of a comprehensive study, carried out within the PON-AIM 2014–2020 project, aimed at the evaluation of the seismic resilience of the examined area.

Keywords: Built heritage · Reinforced concrete buildings · Seismic resilience · Census · Documental analysis · GIS technology

1 Introduction

The definition of potential seismic scenarios and possible resiliency objectives on a territorial scale can be performed at different levels of detail, depending on the territorial unit size, the robustness of seismic hazard data and the accuracy of the vulnerability model. From a practical point of view, the adoption of a building-specific

© Springer Nature Switzerland AG 2020
O. Gervasi et al. (Eds.): ICCSA 2020, LNCS 12250, pp. 899–913, 2020.
https://doi.org/10.1007/978-3-030-58802-1_64

vulnerability model appears a feasible option only for territorial units characterized by a limited size. Moreover, it is worth noting that, in many cases, the built heritage of most of the cities is characterized by homogeneous areas (defined as "compartment"), featuring the same historical, urbanistic and constructive peculiarities. All that considered, the identification of a certain number of territorial-specific structural typologies represents a pragmatic choice for the simplified estimation of the "global vulnerability" of a given area. As a matter of fact, such an approach sensibly reduces the time required for a building-specific approach while maintaining a sufficient accuracy for the preliminary assessment, screening and prioritization of a large building stock.

Different criteria can be adopted for the identification of the structural typologies associated with a given territory. The simpler is the adopted criterion the lower is the accuracy level of the consequent vulnerability assessment. The more elementary typologies inventories classify buildings based on the material of the structural resisting system [1, 2]. However, the inventory accuracy can be significantly improved considering additional information on buildings' peculiarities (e.g. age of construction, number of storeys, non-structural elements dimensions and materials, vertical and horizontal system, etc.).

Several sources of information are available for the inventory compiling. For what concerns the Italian background, the reference database on the built heritage is provided by the Italian National Statistics Institute (ISTAT). Contrary to the data provided by other European countries, the ISTAT database on built heritage is sufficiently stocked. Indeed, data on age of construction, structural material, number of storeys and building area/volume are available. Unfortunately, such data are aggregated at Census Tract (CT) level due to the Italian privacy policy, thus limiting the robustness of the information.

The present paper describes the preliminary activities of a comprehensive research project, funded by the Operative National Program (PON) of Research and Innovation (2014–2010), aimed at the seismic vulnerability assessment, and consequent resilience capacity analysis, of the city centre of Potenza (southern Italy). In particular, an inventory of the main structural typologies of residential Reinforced Concrete constructions is presented herein. Different sources of information have been employed for the inventory compiling: Census data, documentary analyses, site and virtual inspections (i.e. GIS-based analysis). In the first part, aggregated and disaggregated data are presented. In the second part, a number of structural typologies are tentatively identified for the following seismic performance assessment.

2 Previous Approaches for Typologies Inventory Compiling

Building typologies identification is a fundamental preliminary step for any vulnerability or loss assessment process. Indeed, the computational effort associated with a building-specific approach appears unfeasible for areas or regions with a building

population of hundreds or thousands elements. As mentioned before, grouping buildings in a limited number of structural typologies increases the manageability of the examined case-studies maintaining a sufficient accuracy for vulnerability analysis. Obviously, the level of accuracy depends on the completeness and consistency of the assumed classification approach. In the last decades, several international building classification schemes have been proposed. Most of them have been also integrated in comprehensive methodologies for the evaluation of the building vulnerability and implemented within international seismic codes [3, 4]. The building classification schemes are characterized by different levels of detail. The classification with respect to the construction material represents the most basic approach. The latter has been adopted within MSK–64 and later in the European Macroseismic Scale EMS [1, 2]. The second generation of building classifications [5] introduced new and more specific parameters. In particular, age of construction/design code level, primary load bearing structure (only vertical or vertical and horizontal) and total height/number of storeys have been taken into account. Recently, very accurate building classification schemes have been proposed [6]. Specific characteristics (such as orientation of the lateral load-resisting systems, building shape in plan, structural irregularities, exterior wall materials and dimensions, etc.) affecting the seismic performances of the building are considered.

However, it is worth noting that the prevalence of a construction typology on a certain territory depends on many different factors such as: (i) geological and topographical conditions (influencing the local availability of building construction materials), (ii) traditional building technologies, (iii) socio-economic conditions, (iv) meteorological conditions (influencing the selection of materials and non-structural elements dimensions), (v) hazard history, etc. This leads to the existence of several territorial-specific typologies that are not included in the major international building' classifications. As a consequence, many customized classifications have been developed at regional scale. The most common approach for the definition of a customized classification consists in the employment of a Census database as primary source of information. The heterogeneous data provided by Census on buildings are then integrated using other territorial-specific sources of information (documental analysis, virtual and in situ inspections, etc.) [7, 8].

3 Case-Study

Potenza municipality is the chief-town of the Basilicata region (southern Italy) counting a population of about 70.000 people (ISTAT 2011) [15], located on a hill in the axial-active seismic belt (30 to 50 km wide) of southern Apennines. During his history, Potenza was hit by several strong earthquakes (intensity higher than or equal to VIII MCS). In particular, the 1826 and 1857 events caused severe damage in the entire town [9] imposing a massive demolition and reconstruction activity [9] in the historical city

centre. During the 30s and 40s the demographic increment produced the migration of the population to new urban areas located in the north of the city territory. In this context, an important public housing plan was pursued by the local organization of Social Housing (Azienda Territoriale per l'Edilizia Residenziale, ATER) creating two new residential neighborhoods (i.e. Santa Maria and Verderuolo districts). In the aftermath of the Irpinia and Basilicata earthquake (November 1980), a massive reconstruction plan, funded by the Italian Government (law 219/81), involved several existing buildings in the Potenza municipality.

An investigation on the built heritage of the city of Potenza is proposed in this paper. In particular, two main sample areas are chosen for this study: the hilltop town ("old town centre", shown in yellow in Fig. 2 and labeled as C1) and the "residential public housing neighborhood" (shown in blue in Fig. 2 and labeled as C2). Those areas can be considered as homogeneous zones (compartments) featuring specific historical, urbanistic and constructive peculiarities. Moreover, such compartments include most of the historical built heritage of the city, developed in two main periods: 1850–1950 and 1945–1990, respectively. Due to the small amount and specific peculiarities of public buildings, only private residential buildings will be considered herein (Fig. 1).

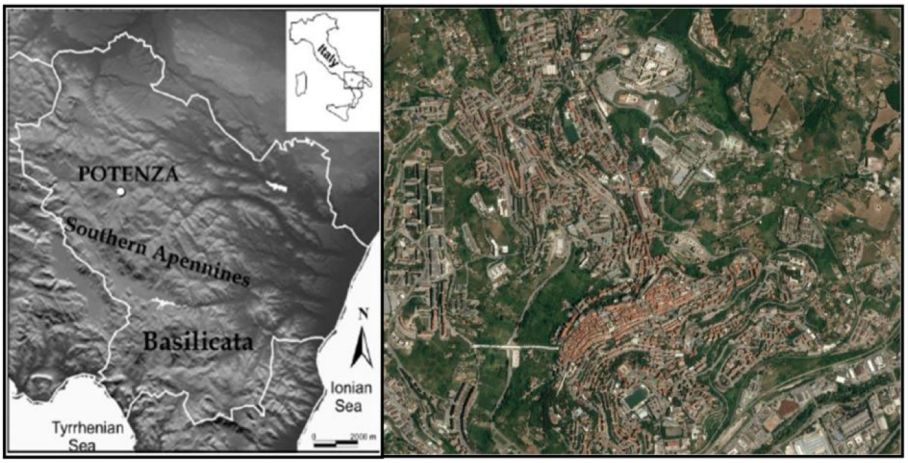

Fig. 1. Geographical location and urban area of Potenza (Basilicata Region, Southern Italy)

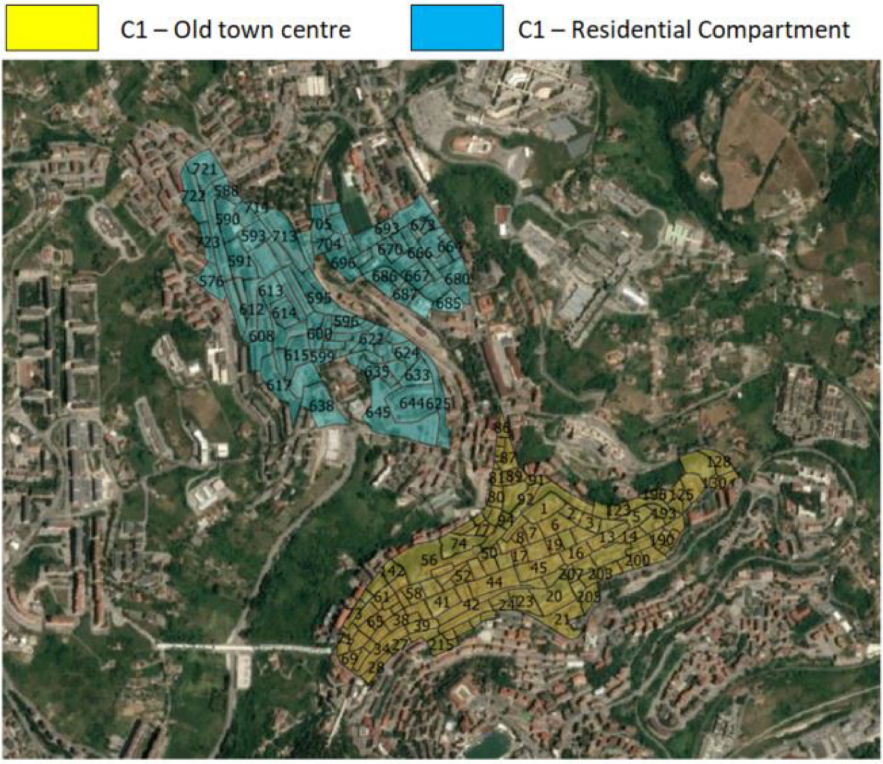

Fig. 2. Census tracts of the old town centre (yellow) and residential (blue) compartments (Color figure online)

4 Building Typologies Inventory Assembling Approach

As mentioned in Sect. 2, in some cases, customized schemes are needed to properly classify the built heritage at territorial scale. In the present paper, a specific building typologies inventory referred to the examined compartments (C1 and C2) is proposed. The assembling approach is based on the combination of two different informative levels. The preliminary source of information is represented by the Census data provided by the Italian Institute of Statistics (ISTAT). Due to the privacy policy, such data are available only in an aggregated form. In other words, while it is possible to know, for example, the number of RC buildings in a certain CT, the user cannot directly derive the number of those buildings featuring 2, 3 or more than 3 storeys or, similarly, the number of RC buildings realized in a specific period of time. As a consequence, a specific de-aggregation procedure is needed in order to use such data for a suitable classification. For this reason, the primary Census data are successively integrated through secondary sources of information represented by extensive documental and virtual analysis and specific building surveys.

4.1 Analyzing Census Data in Aggregated Form

Generally speaking, Census data represent a fundamental source for a building typologies classification. Differently from other European countries, the data provided by the Italian Institute of Statistics (ISTAT) are extremely populated (repeated every 10 years) and homogeneously distributed on the entire national territory. Table 1 summarizes the Census Variables (CVs) provided for each CT within the ISTAT "building database". Figures 3, 4 and 5 show the aggregated restitutions for buildings located in the two examined compartments. For the sake of completeness, some synthetic data are also summarized in Table 2.

Based on the aggregated Census data, some preliminary important considerations can be made. First of all, the data provided in Fig. 3 outline that, in both compartments, the percentage of masonry buildings is prevalent. As expected, this percentage is extremely high in the old town centre (C1), being equal to approximately the 80% (see Fig. 3(a)). However a significant percentage of RC buildings is also observed (approximately equal to 20%).

Table 1. Relevant Census Variables (CV) for buildings (ISTAT 2011)

Census variable	Description
E3	Total number of residential buildings
E5	Number of Masonry residential buildings
E6	Number of Reinforced Concrete (RC) residential buildings
E7	Number of residential buildings realized with other materials
E8	Number of residential buildings built before 1919
E9	Number of residential buildings built in the period 1919–45
E10	Number of residential buildings built in the period 1946–60
E11	Number of residential buildings built in the period 1961–70
E12	Number of residential buildings built in the period 1971–80
E13	Number of residential buildings built in the period 1981–90
E14	Number of residential buildings built in the period 1991–2000
E15	Number of residential buildings built in the period 2001–2005
E16	Number of residential buildings built after 2005
E17	Number of residential buildings with 1 Storey
E18	Number of residential buildings with 2 Storeys
E19	Number of residential buildings with 3 Storeys
E20	Number of residential buildings with 4 or more than 4 Storeys

This is probably due to some political decisions on the old town planning taken between 1945 and 1970 [9, 10]. As a matter of fact, in the mentioned period, many old masonry buildings in the historical centre (namely, C1 compartment) were demolished and replaced by new RC buildings. Similar interventions were carried in the aftermath of the Irpinia and Basilicata earthquake (30th November 1980) that strongly hit the city

centre of Potenza. This lead to a not negligible percentage (around 10%) of RC buildings realized in the period 1981–1990. For what concerns the residential compartment (C2), a percentage of RC buildings lower than 30% is observed (see Fig. 3b)). This is quite unexpected since most of the buildings located in C2 (more than 70%) have been realized during the period 1960–1990 (see Fig. 4(b)), considered as the "golden age" for RC buildings. However, the previous consideration is completely overturned reanalyzing the same data in terms of building volume. Actually, RC buildings located in the residential compartment typically feature a number of stories greater than masonry buildings, so that their average volume is sensibly larger (approximately 3,800 m^3 against approximately 540 m^3) [11]. All that considered, the construction volume occupied in C2 by RC buildings represent approximately the 77% of the total.

Another interesting consideration is that the percentage of buildings realized in the period 1971–1980 and after 1981 is not negligible for both compartments. As a matter of fact, 1971 and 1981 represent turning points from a technical point of view. In the early 1971, new regulations concerning the administrative management of the design process for new buildings were enforced by the Italian Government [12]. Such regulations determined a stronger control on bureaucratic procedures and (structural and non-structural) material' acceptance criteria, while only slight differences in terms of seismic capacity. Actually, the gravity load design philosophy continued to represent the general design practice, leading to RC buildings featuring the same structural peculiarities of those realized in the pre-1971 period. On the contrary, the Irpinia and Basilicata earthquake (1980) forced the Italian Government to introduce some specific regulations for the damaged territories [13], classifying Campania, Puglia and Basilicata regions as seismic zones. As a consequence, buildings realized in the aftermath of the mentioned regulations feature an enhanced seismic behavior taking into account the effect of lateral seismic loads. All that considered, two major classes of buildings can be identified with respect to the age of construction (a_c), or level of code design, namely: pre- and post-1981. The percentages of buildings afferent to the aforementioned classes are reported in columns 5 and 6 of Table 2, respectively.

Finally, considering that the seismic behavior is strongly affected by the structure height, important considerations can be derived analyzing the aggregated data with respect to the number of storeys (n_s).

As showed in Fig. 5, buildings featuring more than 3 storeys (labeled as "4+") are prevalent in both compartments (51% in the old town centre and 78% in the residential compartment). Unfortunately, as mentioned before, based on the Census aggregated data no specific information are available to effectively separate the percentages of medium-rise ($4 \leq n_s \leq 6$) and high rise ($n_s > 6$) buildings. On the other hand, the percentage of low-rise building (namely, 1- to 3-storeys) can be directly estimated appearing not negligible, in particular in the old city centre compartment (being equal to approximately 30%).

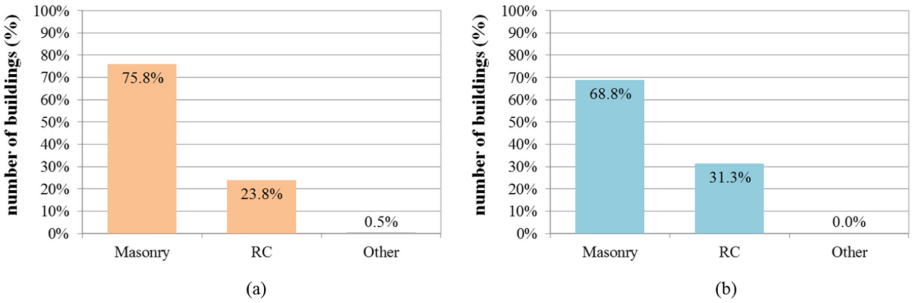

Fig. 3. Percentage distribution of residential buildings in terms of construction materials for (a) old town centre and (b) residential compartments (ISTAT 2011).

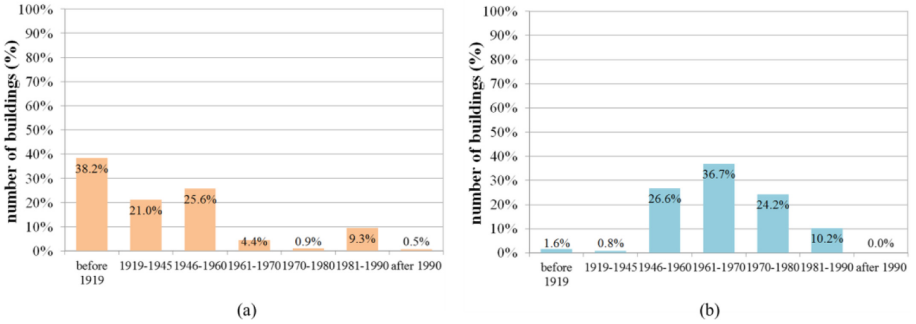

Fig. 4. Percentage distribution of residential buildings in terms of age of construction for (a) old town centre and (b) residential compartments (ISTAT 2011).

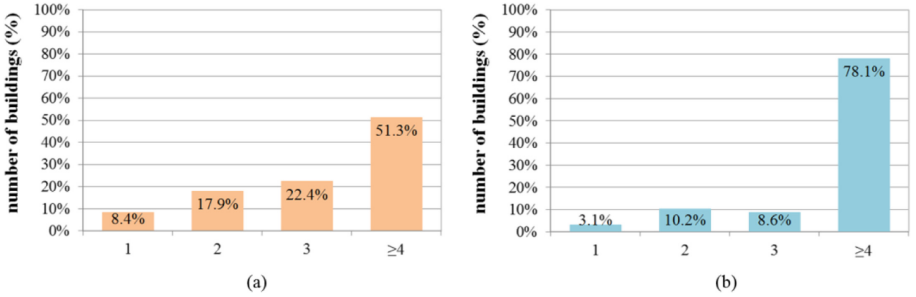

Fig. 5. Percentage distribution of residential buildings in terms of number of storeys for (a) old town centre and (b) residential compartments (ISTAT 2011).

Table 2. Synthetic relevant data referred to the examined compartments (ISTAT 2011)

Compartment	No. of buildings	Masonry	RC	Pre-81	Post-81	$n_s \leq 3$	$n_s > 3$
C1	429	76%	24%	90%	10%	49%	51%
C2	128	69%	31%	90%	10%	22%	78%

4.2 Secondary Sources of Information

Based on the Census data described in the previous section, two main variables emerged as significant classification parameters, namely, the number of storeys (n_s) and the age of construction (a_c). Innovative techniques such as GIS-technology and High Resolution optical satellite imagery have been used to rapidly collect geo-referenced information on the number of storeys of the building stocks located in the examined compartments [14], thus allowing a proper de-aggregation of the mentioned Census data. In order to limit the number of typologies for a suitable management of the building inventory, three macro-classes of buildings have been defined with respect to the parameter n_s. As a matter of fact, several studies confirmed that, all other variables being equal, RC buildings characterized by 1 to 3 storeys (low-rise buildings) exhibit approximately the same seismic response [7, 8]. Similar considerations can be drawn for buildings featuring 4 to 6 storeys (medium-rise buildings) and for buildings with 7 to 10 storeys (high-rise buildings). As a consequence, the following classes have been defined herein: "Lr" (1–3 storeys), "Mr" (4 to 6 storeys) and "Hr" (7 to 10 storeys).

With reference to the second parameter (namely, a_c), two major classes of buildings have been identified: Pre- and Post-1981. Clearly, the identification of these two groups of buildings is not merely temporal but is more properly related to the reference design code. As a matter of fact, the introduction of new seismic regulations [13] led to specific peculiarities for buildings designed after 1981. In order to identify the main characteristics of the two mentioned classes of buildings (pre- and post-1981), a comprehensive documental analysis has been carried out. In particular, a large database provided by the local organization of Social Housing (Azienda Territoriale per l'Edilizia Residenziale, ATER), strongly involved in the residential compartment construction and in the post-seismic reconstruction, has been analyzed. Moreover, some building-by-building surveys, providing detailed data for both dimensional and structural peculiarities for a single building in an investigated area, have been performed. Finally, several information have been gathered interviewing local technicians with deep knowledge of the construction characteristics.

Table 3 summarizes the main peculiarities of pre- and post-1981 buildings derived from the aforesaid investigation. As can be seen, the typical lateral resisting system of pre-1981 buildings is characterized by perimeter and internal mono-directional resisting frames (RC frame buildings). External deep beams (characterized by a size reduction at higher floors) and internal shallow beams were typically adopted. On the contrary, resisting frames in both principal directions with a wide use of shallow beams has been generally observed for post-1981 buildings. Important information regarding non-structural elements have been also collected. In particular, pre-1981 buildings feature heavy masonry infills (generally constituted by solid bricks) in the most of

Table 3. Main peculiarities of pre- and post-1981 buildings.

	Design code level	Resisting system	Structural elements	Non-structural elements	Horizontal system
Pre-1981	Gravity load design	– Perimeter resisting frames – Internal resisting frames in only one direction	– External deep beams internal shallow beams – Staircase: knee beams and cantilever steps	– Heavy masonry infills (solid bricks) – Light double layer masonry infills in some cases (buildings realized between 1960 and 1980)	– Unidirectional reinforced concrete T-beams and hollow tiles mixed floor
Post-1981	Earthquake resistant design	Resisting frames in both principal directions	– External deep beams (size reduction at higher floors); Wide use of internal shallow beams. – Staircase: knee beams and cantilever steps; Waist-slab staircases in a few cases realized in the 90 s	– Light masonry infills – Hollow clay bricks arranged in two layers (12 + 8 cm) separated by a 10 cm interspace	– Unidirectional reinforced concrete T-beams and hollow tiles mixed floor

Table 4. Preliminary macro-typologies inventory for the examined compartments

Macro typology ID	Description
L	Bidirectional resisting system Light masonry infills Earthquake resistant design
M	One direction resisting system Light masonry infills Gravity load design
H	One direction resisting system Heavy masonry infills Gravity load design



Fig. 6. Example of Pilotis-storey building (Via Roma, Potenza – C2 compartment).

cases. Light masonry infills (realized using a double layer of hallow bricks 10 + 10 cm or 12 + 8 cm) have been observed in a limited number of cases, in particular for buildings realized in the period 1960–1980. External masonry infills constituted by hollow clay bricks arranged in two layers (12 + 8 cm) and separated by a 10 cm cavity were typically adopted for post-1981 buildings. Clearly, the combination of the mentioned characteristics for each class of buildings produces a different seismic behavior and, as a consequence, a different seismic vulnerability.

Table 5. Building typologies inventory for the examined compartments

Macro typology ID			Number of storeys			Staircase typology		Vertical irregularities		ID
L	M	H	Lr	Mr	Hr	K	s	PF	IF	
x			x			x		x		L,Lr,k,PF
x			x			x			x	L,Lr,k,IF
x			x				x	x		L,Lr,s,PF
x			x				x		x	L,Lr,s,IF
x				x		x		x		L,Mr,k,PF
x				x		x			x	L,Mr,k,IF
x				x			x	x		L,Mr,s,PF
x				x			x		x	L,Mr,s,IF
x					x	x		x		L,Hr,k,PF
x					x	x			x	L,Hr,k,IF
x					x		x	x		L,Hr,s,PF
x					x		x		x	L,Hr,s,IF
	x		x			x		x		M,Lr,k,PF
	x		x			x			x	M,Lr,k,IF
	x		x				x	x		M,Lr,s,PF
	x		x				x		x	M,Lr,s,IF
	x			x		x		x		M,Mr,k,PF
	x			x		x			x	M,Mr,k,IF
	x			x			x	x		M,Mr,s,PF
	x			x			x		x	M,Mr,s,IF
	x				x	x		x		M,Hr,k,PF
	x				x	x			x	M,Hr,k,IF
	x				x		x	x		M,Hr,s,PF

(*continued*)

Table 5. (*continued*)

Macro typology ID			Number of storeys			Staircase typology		Vertical irregularities		ID
L	M	H	Lr	Mr	Hr	K	s	PF	IF	
	x				x		x		x	M,Hr,s,IF
		x	x			x		x		H,Lr,k,PF
		x	x			x			x	H,Lr,k,IF
		x	x				x	x		H,Lr,s,PF
		x	x				x		x	H,Lr,s,IF
		x		x		x		x		H,Mr,k,PF
		x		x		x			x	H,Mr,k,IF
		x		x			x	x		H,Mr,s,PF
		x		x			x		x	H,Mr,s,IF
		x			x	x		x		H,Hr,k,PF
		x			x	x			x	H,Hr,k,IF
		x			x		x	x		H,Hr,s,PF
		x			x		x		x	H,Hr,s,IF

Based on the aforementioned considerations, a preliminary typologies inventory, in terms of seismic vulnerability, can be defined. In particular, three different macro-typologies can be considered, featuring Low [L], Medium [M] and High [H] vulnerability (see Table 4). The preliminary inventory proposed in Table 4 can be further refined considering other specific building characteristics (namely, "attributes") that effectively affect the seismic behavior. Besides the aforementioned number of storeys (n_s), significant attributes emerged from the described documental and in situ investigation (see Table 5). Among those, irregularities in elevation and staircase typology cannot be ignored for a comprehensive evaluation of the building typologies. Vertical irregularities are frequent for both pre-1981 (generally for those built in the 70s) and post-1981 (namely, 80s and 90s) buildings. In particular, such irregularities are mainly represented by an open ground storey (pilotis-storey, PF) as shown in Fig. 6. Similarly, two main staircase typologies have been observed, although knee beams with cantilever steps represented the typical solution for pre-1981 buildings and for most of post-1981 buildings. Waist-slab staircases have been observed in a few cases for post-1981 buildings (generally for those realized in the 90s).

It is worth noting that slightly differences have been observed in terms of other attributes, such as roof type, horizontal floor types (always constituted by composite RC beams and clay blocks), state of preservation, etc. As a consequence, such attributes have been neglected in the final inventory. Finally, it is also worth noting that the (in plan) structural configuration and the structural element dimensions (derived from the described investigation) will be opportunely taken into account at a later stage of the analysis and, in particular, during the numerical modeling of the selected archetype buildings. The final building inventory, obtained adopting the classification approach described in the previous sections is shown in Table 5. As can be seen, a total of 36 classes have been identified.

5 Conclusions

In this paper, a simplified approach aimed at the assembling of a building typologies inventory is presented and applied to the urban residential area of Potenza (southern Italy). In particular, the proposed approach combines the primary-level information collected by a Census-based database with a complementary informative database based on specific documental/virtual analysis, building-by-building surveys and expert judgment. A preliminary inventory composed by three macro-typologies has been defined based on heuristic criteria. Such preliminary inventory has been then refined considering specific building structural peculiarities affecting the seismic behavior. Thereby, 36 typologies have been identified.

The research activity described in this paper represents the primary step of a comprehensive study for the evaluation of the seismic resilience of the investigated area. A complementary study, regarding the masonry residential buildings located in the same compartments, has been carried out in parallel by the same authors of this paper.

Acknowledgments. This research was funded by the PON-AIM 2014–2020 project supported by the Italian Ministry of University and Public Instruction.

References

1. Grunthal, G.: European Macroseismic Scale (EMS-92), Chaiers du Centre Européen de Géodynamique et de Séismologie, 15 (1992)
2. Grunthal, G.: European Macroseismic Scale (EMS-98), Cahiers du Centre Européen de Géodynamique et de Séismologie, Luxembourg (1998)
3. ATC (Applied Technology Council): Earthquake Damage Evaluation Data for California, Applied Technology Council Report ATC-13, Redwood City, CA (1985)
4. Federal Emergency Management Agency: FEMA 154 – Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook. Earthquake Hazards Reduction Series 41, 2nd edn. (2002)
5. Federal Emergency Management Agency: HAZUS-MH MR4 Technical Manual, Washington, D.C. (2003)
6. Brzev, S., Scawthorn, C., Charleson, A.W., Jaiswal, K.: Interim overview of GEM building taxonomy V2.0. Report produced in the context of the GEM Building Taxonomy Global Component, Version 1.0 (2012)
7. Polese, M., Gaetani d'Aragona, M., Prota, A.: Simplified approach for building inventory and seismic damage assessment at the territorial scale: an application for a town in southern Italy. Soil Dyn. Earthq. Eng. **121**, 405–420 (2019)
8. Corlito, V., De Matteis, G.: Typological-structural characterization and seismic vulnerability assessment of reinforced concrete buildings in the Caserta district through the parameters of the CARTIS form. In: XV Convegno Nazionale ANIDIS, L'ingegneria Sismica in Italia, Ascoli Piceno (2019)
9. Gizzi, F.T., Masini, N.: Historical earthquakes and damage patterns in Potenza (Basilicata, Southern Italy). Ann. Geophys. **50**(5) (2007)
10. Dolce, D., Masi, A., Marino, M., Vona, M.: Earthquake damage scenarios of the building stock of Potenza (Southern Italy) including site effects. Bull. Earthq. Eng. **1**, 115–140 (2003). https://doi.org/10.1023/A:1024809511362
11. Chiauzzi, L., Masi, A., Mucciarelli, M., Vona, M., et al.: Building damage scenarios based on exploitation of Housner intensity derived from finite faults ground motion simulations. Bull. Earthq. Eng. **10**, 517–545 (2012). https://doi.org/10.1007/s10518-011-9309-8
12. Norme per la disciplina delle opere di conglomerato cementizio armato, normale e precompresso ed a struttura metallica (GU n.321) (1971). (in Italian)
13. Decreto Ministeriale: Dichiarazione in zone sismiche nelle regioni Basilicata, Campania e Puglia, 7 March 1981. (in Italian)
14. Comber, A., et al.: Using shadows in high-resolution imagery to determine building height. Remote Sens. Lett. **3**(7), 551–556 (2012)
15. (ISTAT 2011) 15° Censimento della popolazione e delle abitazioni, Istituto Nazionale di Statistica (ISTAT), 9 October 2011 (in Italian)