Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

MANUAL FOR THE COMPILATION OF THE 1° LEVEL FORM FOR THE TYPOLOGICAL-STRUCTURAL CHARACTERIZATION OF URBAN SECTORS CONSISTING IN ORDINARY BUILDINGS

CARTIS 2017

by:

Reluis Project 2014-2016
Research Line "Development of a systematic methodology for assessing the exposure on a territorial scale, based on the typological-structural characteristics of the buildings"
Research Unit of the University of Naples Federico II

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Introduction

The **first level CARTIS form** aims at surveying the prevalent ordinary building typologies within municipal or sub-municipal areas, hereinafter referred to as Sectors, characterized by homogeneity of the building stock by period of construction and/or building structure and techniques.
The CARTIS form refers only to ordinary buildings, such as those, mainly for residential use or services, object of the AeDES form and its manual. It is mostly about multi-storey buildings, characterized by masonry or reinforced concrete structures, framed or with RC walls, and with modest size of storey heights and structural grid. Therefore, monumental buildings (religious buildings, historic buildings, etc.), special structures, (industrial warehouses, shopping centers, etc.) or strategic buildings (hospitals, schools, barracks, prefectures, civil protection offices, etc.), whose characteristics do not fall within those of the ordinary buildings, are excluded from the form.

The form has been developed as part of the three-year ReLUIS 2014-2016 project, within the line of research "Development of a systematic methodology for assessing the exposure on a territorial scale, based on the typological/structural characteristics of the buildings", in close collaboration with the Department of Civil Protection (DPC).

It makes use of the knowledge and experience gained in a previous work of typological characterization on the national territory carried out by the Research Unit of Naples (now the PLINIVS-LUPT Study Center), under an agreement with the National Seismic Service, today Seismic and Volcanic Risk Office of the DPC entitled "Structural Typological Characterization Model on a National Scale" Convention Rep. 163 - of 11.12.2000, as well as similar experiences, also conducted by the DPC.

As highlighted in the final report of the aforementioned project, the structural typological characterization study was born with the intention of investigating the national construction typologies, qualitatively identifying the features of local buildings. In fact, the buildings techniques, throughout the Country and over the centuries, due to local cultures and conditioning, have significantly affected the attributes and the quality of buildings, determining substantial differences also in terms of seismic response. The operational implications resulting from a detailed structural typological analysis are several and all particularly important.

Among these, a relevant aspect regards the possibility of providing indications for a regionalization of the vulnerability functions currently used indifferently throughout the national territory. The identification and recognition of the prevalent structural typologies in Italy undoubtedly represents the first step to be taken in the context of a more thorough and detailed building vulnerability assessments. At present, in fact, the researchers are busy, on the one hand, in the definition of methodologies that, on the basis of "poor" data, allow to build the inventory of the national building stock (divided into typological classes of vulnerability according to the macroseismic scales) and on the other hand, on the possible regionalization of the Probability of Damage Matrices (DPM), currently calibrated on the basis of data referring to limited territorial areas with very characterizing data in the structural aspect. The identification of homogeneous areas for structural typological characteristics (with a focus on masonry buildings, which, as is known, are very common in our historic centres with a variety of configurations), together with detailed analyses capable of substantiating a structural typological regionalization, is addressed to contextualize the current DPM and to provide the tools to a more rational utilization at national level.

There is no doubt, as it can be understood from what is mentioned above, that the analysis of the typological structural characterization lends itself to multiple applications and provides different operational implications. Among these, the primary objective of this methodology is **to provide useful elements to improve the inventory of the structural typological distributions on the national territory which, as is well known, represents a crucial point for the large-scale vulnerability and risk analysis, carried out with any approach (empirical statistic, mechanical-numerical, combined, or other)**.

General instruction for compiling the form

For each municipality investigated, the form must be filled by an expert from the ReLUIS Research Unit (RU), with the help of an interview with a local technician or belonging to a Public Body (Region, Province, Municipality, Mountain Community, Civil Engineering Department) as well as professional with reliable knowledge of the area under study.

Preliminarily, the surveyor have to contact a representative of the investigated Municipality, who will suggest the most suitable interlocutors for the purpose, internally and or externally of the administration itself.

The compilation of the form must follow a path in which the information is acquired by the surveyor, a researcher of the RU, with a critical spirit, using the information obtained from the "interviews" with one or more local technicians having an in-depth knowledge of the entire municipal area or the individual Sectors. In any case, it is suggested to perform one or more visits, during and/or at the end of the interviews, to get a first idea of the studied area and to verify the consistency of the acquired information, starting from the correspondence between the delimitation of the sectors and the features assigned to them.It is suggested that at least one of the visits is conducted jointly with the interviewed, so that any inconsistencies can be resolved immediately.

Finally, it is important that he surveyor, preliminarily to the interviews, proceed to an autonomous "study" of the territory, to improve the critical spirit in the collection of the information and, above all, to better understand the information that will be provided to him. The delimitation of the Sectors should be done considering information from historical, bibliographic and documentary investigations, which allow to understand the construction phases and from these implicitly drawn the delimitation of the sectors.

The bibliographic and documentary investigations may be accompanied by cartographic and cadastral documentation. It is useful to consult aerial and satellite images, even using the most modern of the WEB.

It is important to underline that only the information obtained through interviews and from reliable and complete sources are to be reported, and not those deduced only for the final purpose to fill in the form in all its parts. The form, in fact, must report only the information of which there is good "certainty", obviously within the limits of the reliability of the interlocutor and the feedback that the compiler has carried out. Therefore, the form does not necessarily have to be completed in all its parts.

The fields left empty will indicate the absence of reliable information.

It is important to point out that any doubts regarding how to fill in the form must be dispelled in view of its main objective, that is namely the evaluation of the seismic response of the typology in question.

Criteria for the delimitation of the Sectors

The subject of the Cartis survey is the entire municipal area, including any hamlets or localities, if significant for number of buildings and for typological characterization. The preliminary phase of the work involves the recognition of the homogeneous Sectors, which will be appropriately delimited on the map (to be attached to the form), tracing the boundaries, and progressively numbered. The Sectors are homogeneous areas which are characterized by the presence, within them, of homogeneous buildings from a structural typological point of view and by period of construction.

Although the Cartis form permits to indicate maximum 8 typologies for each Sector (4 of masonry and 4 of reinforced concrete), it is in the spirit of the entire methodology to limit the identification of the typologies to those that effectively are representative for the Sector.

The preparatory material for the delimitation of the Sectors consists, possibly, of:

- municipal basic cartography CTR (recommended for small and medium centres 1: 5.000 or higher in the case of larger urban centres);
- orthophoto;
- any cadastral maps of different periods;
- any aerial photos, even of different periods;
- General regulatory plan (PRG) and any detailed plan (PP);
- any other urban planning tools in force of the administration (recovery plans, structural plans).

The overlay of the basic cartography with a chronological city development map, or, in absence, the comparison among the cadastral maps of different periods, allows to frame the growth phases of the city and to date them (Figure 1).

Figure 1. Chronological development map of the City of Solarolo (RA).

From these documents it is possible to identify the historical areas (built previously to1919), those prior to 1974, the areas built prior to first seismic classification of the municipality, as well as the areas built after these important dates in the case of more recent buildings.

This first screening will serve, for example, to define the areas with masonry buildings (as historical areas), from those with buildings in RC and, among the latter, also indicating the buildings designed with seismic criteria.

Where such documents are not available, a careful examination of the orthophotos will allow the delimitation of at least the historical centre.

Instructions for completing the CARTIS form

The form is organized into the following 4 sections:

1. **Section 0** to identify the municipality under consideration and the Sectors identified therein;
2. **Section 1** for the identification of each of the prevailing typologies characterizing the generic Sector of the Municipality considered;
3. **Section 2** for identifying the general characteristics of the typologies under consideration;
4. **Section 3** for characterization of the structural elements of the typology under consideration.

The required information must be specified by ticking the corresponding boxes or by entering alphanumeric data. The presence of square boxes (□) indicates the possibility of multi-choice, while the round boxes (O) indicate the possibility of a single choice. Where the boxes ⊔ are present, it is necessary to insert text or numbers in block letters, placing the text on the left and the numbers on the right.
The percentages, where required, must be rounded to the nearest unit, while the measurements requested will be appropriately rounded in relation to the level of knowledge and the statistical significance of the value within the typology under examination.
**See note on last page

Instructions for completing Section 0: Municipality and Sector Identification

The objective of **Section 0** is to identify the municipality and the Sectors therein identified by the Research Unit with the assistance of the interviewed technicians. It must be completed for each municipality examined and is divided into two parts, A and B.
Part A collects the following information:

a. ***Location data***: Region, Province, Municipality and Hamlet/locality.

b. ***General information of the municipality***: total number of residents; year of first seismic classification; year of adoption of the last General Regulatory Plan or Manufacturing Program ("Programma di Fabbricazione"); Name, email and signature of the person filling in the form. Presence of Detailed Plan for the Historic Center; total number of dwellings and buildings[1] obtained from ISTAT Census and field survey[2].

c. ***Number of homogeneous zones (Sectors)***.
The number of sectors depends on the extension of the built-up area and on the homogeneity of the building fabric in terms of period of construction and/or building techniques. In the individuation of the Sectors can be of help a study of the chronological evolution of the Municipality in reason of the historical events that have characterized it, according to the criteria previously exposed. In general, also for small municipalities it is advisable to assume at least 2 sectors, distinguishing between "Historic Center" and "Expansion Area", starting the numbering always from the Historic Center (number 1) and proceeding the numbering progressively. If the historical center is characterized by more sectors, their numbering will be progressive, always starting from 1.

d. ***Information on the Reluis Research Unit (RU)***: identification code assigned by the Coordination of Reluis Line II "Territorial Risk"; RU contact person (identified by the Responsible of the Reluis Line); affiliation entity (University or Research Institute), qualification, degree, address, email and telephone numbers of the RU contact person.

e. ***Information on interviewed technicians***: name and telephone number of the Municipality's Contact Person; name of the organization they belong to (Region, Province, Municipality, Mountain Community, Civil Engineering, Private Office, Freelance, etc.) and, where applicable, qualification (Director/chief, official, engineer/architect/surveyor; Address, email and telephone numbers of the two possible interviewees (one of which may or may not coincide with the Municipality's Contact Person).

f. ***Plan of the Municipality with the identification and numbering of the Sectors***:
Since the space dedicated to the map is very small, it is advisable to work on a map in scale, as specified in the previous paragraph, and report in the dedicated space a reduction of the map in clean. Each sector must be indicated with an abbreviation consisting of the letter "C" followed by a progressive number (for example, C1, C2, etc.), congruent with the numbering in entry c.

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[1] *A building is a structural unit "sky ground", identifiable by typological characteristics and therefore distinguishable from adjacent buildings for these characteristics and also for difference in height and / or age of construction and / or staggered floors, etc. (AeDES).*

[2] *Numbers of dwellings and buildings "surveyed" can be obtained from site surveys previously carried out by the municipality (e.g., for tax reasons), by the UR itself or by counting through detailed maps able to operate with an acceptable margin of error a count of the structural units present starting from the distinction of the roofs. of error a count of the structural units present starting from the distinction of the covers. Additional tools to assist in these operations are satellite images, automatic recognition with dedicated software, georeferenced photos (such as Google Street View), etc.*

Part B collects, for each Sector identified on the plan in Section 0/Part A, the following information:

- ***a. Code*** (C01, C02, C03, ..., prefixed).
- ***b. Sector name*** (e.g: Historic Center 1, Historic Center 2, Expansion Zone 1, Expansion Zone 2, Tourist Zone,...).
- ***c. Period of construction***, indicating, according to the available information the century (e.g. for historical center or first settlement) or the decade (e.g, for expansion areas). The century must however be expressed as a year, through 4 digits (14th century = 1300; 1970s = 1970).
- ***d. Residents in the Sector***.
- ***e. Buildings and covered area***. For the number of buildings the same as expressed in note 2 of this text. The covered area must be understood as the footprint on the ground of the buildings and can be deduced from cartographic or vectorized data if available.
- ***f. Households***. The elaboration of this data can be requested, if necessary, from the registry office of the Municipality.
- ***g. Typologies in the Sector***. The form provides, for each Sector the identification and percentage distribution of its most representative typologies, with the possibility of identifying up to 4 typologies of masonry (MUR 1, MUR 2, MUR 3 and MUR 4) and 4 typologies in reinforced concrete (CAR 1, CAR 2, CAR 3 and CAR 4). Each typology identified must be associated with a percentage of presence with respect to the Sector, to be estimated with reference to the total number of buildings in the Sector. The sum of the percentage distributions of the types identified can be less than 100% if in the Sector there are typologies that are not representative of the same in a percentage not exceeding 5%. Although it is possible to identify up to 8 typologies overall per sector, it is opportune to limit the number of typologies to those that are effectively representative of the same, in order not to vain the characterization of the territorial sector.
- ***h. Information reliability***. The interviewed technicians are asked to express the average degree of reliability of the information provided (low, medium, high).

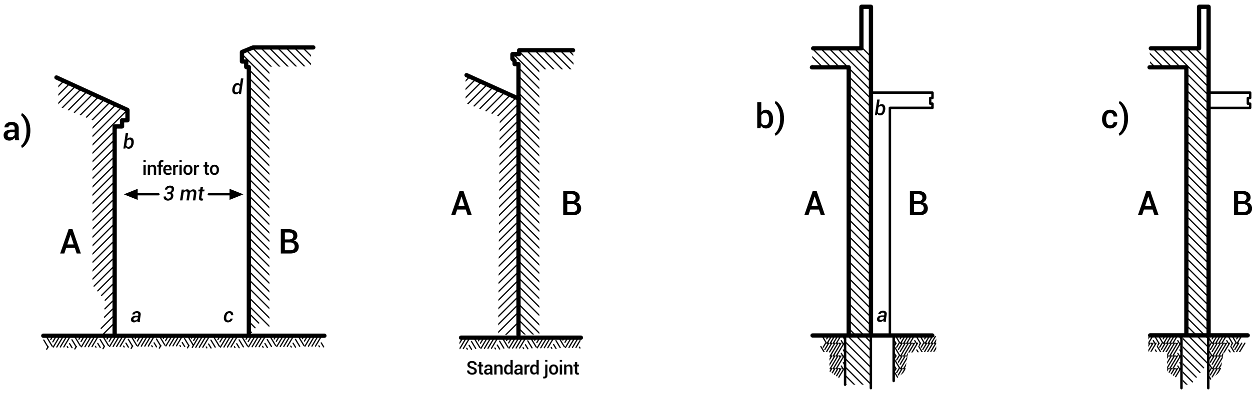
Instructions for completing Section 1: Identification of the typology

The objective of **Section 1** is to identify each of the prevalent typologies characterizing the generic Sector of the assigned Municipality. Like the subsequent sections, it must be completed for each typology of the generic Sector of the assigned Municipality.
Section 1 collects the following information:

- ***a. Typology code***. It is required to cross the code of the typology identified in Section 0 (MUR 1, MUR 2, MUR 3, MUR 4, CAR 1, CAR 2, CAR 3 or CAR 4) with reference to the generic sector for the assigned municipality.
- ***b. Identification code of the typology within the Sector (IDT)***, which unambiguously identifies the typology under examination. It consists of a 15-digit alphanumeric string obtained from a succession of 5 codes: ISTAT Region Code, ISTAT Province Code, Municipality ISTAT code, Sector code, Typology code.
- ***c. Position of the typology in urban context***. In order to investigate the nature of possible interactions between buildings under earthquake (such as, for example, pounding between statically independent contiguous structures), a percentage description (the sum of the three percentages must add to 100) of the location of buildings of the typology under consideration in the urban context is required: isolated; adjacent/ statically independent (but possibly dynamically interacting) structures; connected/interacting structures, both statically and dynamically (Figure 2). If the interviewed technicians do not have sufficient information to distinguish percentages of "adjacent" structures from "connecting" structures, only the percentage of "aggregate" buildings may be indicated.

d. ***Images of the typology***. A photograph is required of a building representative of the typology under examination.
e. ***Plan and section***. A plan and a typical section of the typology under examination are required,

Figure 2. Position of the typology in urban context*:*
a) isolated; b) adjacent buildings (independent structures); c) in connection (interactive structures).



Instructions for the compilation of Section 2: General features

Section 2 aims to describe the general features of the typology in question. It must be completed for each typology of the generic Sector of the municipality in exam. In this section, as in the following sections, the fundamental information to define the typology are highlighted (through a box with a thicker edge).
Section 2 collects the following information:

a. ***Number of storeys including basements***. Is required to indicate maximum two values which indicate the ranges of variability of the number of storeys (including basements) which charatacterises at least the 80% of the buildings included in the typology (approximately 10%-90%). If the relationship (maximum/minimum) between the values indicated were greater than 3, is recommended to introduce two typologies, essentially characterized by different number of stories (e.g., if the minimum were 2 and the maximum was 7, we could identify two typologies with ranges 2-4 and 5-7).
It is to be noted that the total number of storeys refers to those which can be counted starting from the foundation level, including the eventual attic, but only when practicable. Basements are defined as those having an elevation above the ground level (i.e., the average elevation in case of buildings on slope) lower than half of the total storey height (AeDES Manual).
b. ***Average storey height***. Is required to indicate the range of variability of the storey height which charatacterises most of buildings in the typology.
c. ***Average ground storey height***. Is required to indicate the range of variability of the ground storey height which charatacterises most of buildings in the typology.
d. ***Basements***. Is required to indicate the number of basements which charatacterises most of buildings in the typology.
e. ***Average storey surface***. Is required to indicate maximum two values of the ranges of variability of the storey surface (of each building) which charatacterises at least the 80% of the buildings included in the typology. If the relationship (maximum/minimum) between the values indicated were greater than 3, is recommended to introduce another typology.
f. ***Period of construction***. Is required to indicate maximum two values of the ranges of variability of the period of construction which charatacterise at least the 80% of the buildings included in the typology.
g. ***Main use***. Is required to indicate the main uses which charatacterise at least the 80% of the buildings included in the typology.

Instructions for the compilation of Section 3: Structure features

Section 3 aims to describe the structural elements of the typology in question. It must be completed for each typology of the generic Sector of the municipality in exam.
Section 3 is divided into three parts: 3.1A, 3.1B and 3.2. Sections 3.1A and 3.1B are alternative to each other, while Section 3.2 must always be completed.
Section 3.1A is about types of masonry. Unlike the AeDES, the CARTIS form contemplate the association of only one type of masonry and mixed structures, whose classification takes place through the following information:

a. ***Types of masonry***. It is required to indicate the type of vertical structure of the typology under consideration, with respect to the expected seismic response.
The CARTIS form provides for a synthetic classification of masonry by leading back the types of masonry to three macro classes, "regular", "hewn" and "irregular", in relation to their layout. It should be noted that although this classification is taken from the AeDES manual, in the AeDES form this classification is in support of the final judgment on the mechanical quality of the masonry, the only parameter required to the AeDES surveyor.
A more detailed classification of the different types of masonry, considering the variety of situations of the Italian building stock, is provided in tables 1 - 4, with the aim of guiding the surveyor in recognizing and correctly assigning the building typology (AeDES Manual).
Based on the analysis of the exterior wythe, masonry is classified into three large families (AeDES Manual):

- ***Irregular masonry (code A)***, constituted by elements without any regular shape, which may be small or medium size river pebbles, smoothed and with rounded edges (coming from floods or from riverbeds) or may be "scapoli di cava", chips of stone, etc., or otherwise elements of different size with sharp edges, generally made of limestone or lava stone (Tables 1 and 2);
- ***Hewn masonry (code B)***, constituted by elements only roughly worked, not perfectly rectangular dressed, which appear as semi-regular or flat-cut, called sometime "a soletti" (Table 3;
- ***Regular masonry (code C)***, constituted by regular shape elements, perfectly rectangular dressed, as it is possible to obtain from tuff and some other stones, and also, as obvious, by bricks (Table 4).

In any case, the layout may be or not strengthened with brick or regular stone layers at an almost constant spacing (of the same order of magnitude of the thickness). The presence of brick layers is to be considered when the horizontal layers are located at no more than 1/1.5 m. If there is no information on materials, it is suggested to indicate at least the macroscopic characterization of the masonry (irregular, hewn or regular).

b. Three-leaf stone masonry. It is required to indicate the presence/absence of three-leaf stone masonry ("a sacco") which charatacterises most of buildings in the typology.
By three-leaf stone masonry masonry we mean a masonry made of two external wythes, made of bricks or stones with different sizes and processing and spaced apart, whose function is of containment of an inconsistent filling between them, often consisting of a mixture of crushed stone and leftovers, loose or bonded with cement or lime mortar. In the case two wythes masonry without an internal filling, the option to be indicated is "NO".

c. Tie rods or tie beams. Is required to indicate the percentage of building in the typology with presence of tie rods or tie beams. The evaluation of the presence of tie rods or tie beams must be done globally.

d. Bond stones. Is required to indicate the presence or absence of connection elements (bond stone, elements crossing up 2/3 of the wall thickness, other) in the wall thickness of two-wythes masonry walls. Examples are reported in Figures 3 and 4.

e. Presence of buttresses. Is required to indicate the presence or absence of buttresses in the buildings of the typology under consideration.

f. ***Average wall thickness at the ground storey***. Is required to indicate the average wall thickness at the ground storey (in centimeters) which charatacterises the building of the typology under consideration.

g. ***Average distance between walls***. Is required to indicate the average distance between walls wall thickness at the ground storey (in meters) which charatacterises the building of the typology under consideration (Figure 5).

Figure 3. Masonry wall with well connected wythes or with a single wythe (AeDES Manual).

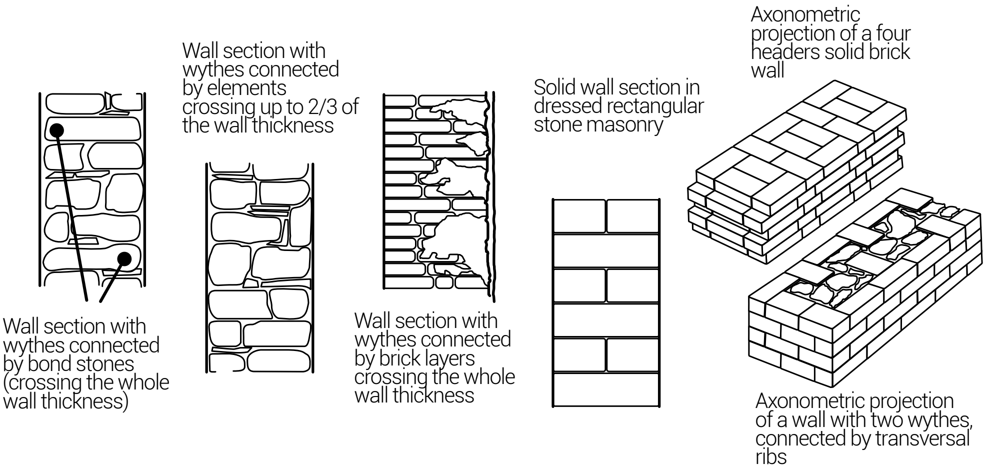
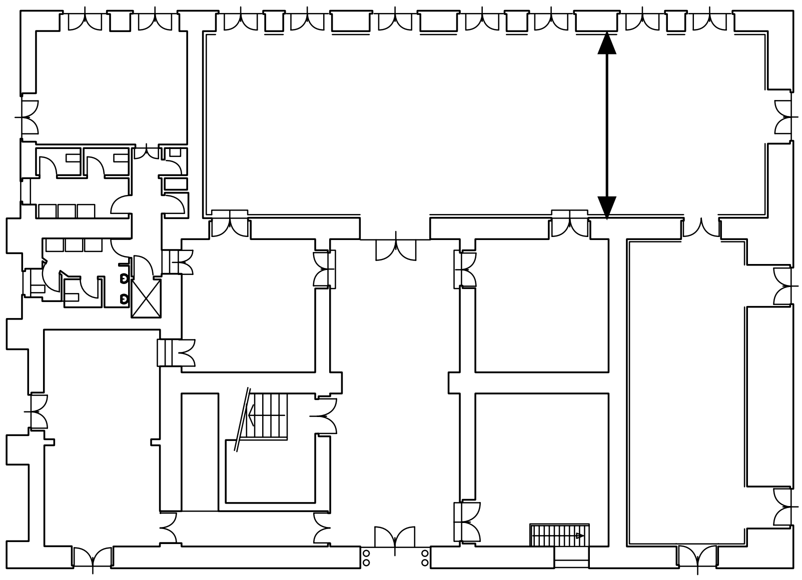


Figure 4. Masonry wall with non connected or badly connected wythes, as highlighted by the disastrous collapses due to the earthquake (AeDES Manual).

Figure 5. Distance between walls



h. ***Types of flat floors***. Is required to indicate maximum two types of flat floors, coexistent or not in the same building, which charatacterise the buildings of the typology under consideration. In analogy to the AEDES, the CARTIS form distinguishes flat structures in the following three typologies, in relation to their in plane flexibility (AeDES Manual).

- ***Beams with flexible slab***: the flexibility and/or the reduced resistance of this typology, even if the floors are well connected to the walls (condition that is almost never met), does not allow to restrain the walls under the out of plane actions, nor to transfer the out of plane seismic force to the transversal walls. It may hence happen that these types of floors facilitate the out of plane collapse of the walls. Wooden floors with single or double direction of spanning (beams and joists), with a simple wood plank or brick elements ("mezzane"), eventually completed with a slab realised in incoherent material or debris ("gretonato") may be considered flexible floors. Flexible floors may also be floors made of iron beams supporting shallow arch vaults made of bricks, stone or concrete. In both cases, if a stiffening element has been introduced, with two perpendicular layers of wood plank flooring or, even better, a reinforced slab well connected to the beams, such floors could be considered as rigid or semirigid, based on the level of connection among elements (Table 5).
- ***Beams with semirigid slab***: the stiffness and the resistance of this typology determine the fact that, if the floors are well connected to the vertical walls (condition mostly verified in case there are tie beams and/or dovetails and effective seams), they are able to act as a sufficiently rigid restrain for the out of plane overturning and to transfer the out of plane seismic force to the transversal walls. These floors, however, are not sufficiently rigid to enforce a rigid floor redistribution of the seismic forces among all the building walls. Several type of floors may be considered semirigid: wooden floors with two perpendicular layers of wood plank flooring, eventually completed with a reinforced concrete slab; floors mad of iron beams supporting hollow flat blocks with a flat intrados; floors constituted by prefabricated reinforced hollow clay tile floor beams, with reinforced concrete ring beams, without any upper reinforced concrete slab (Table 6).
- ***Beams with rigid slab***: the stiffness and the resistance of this typology determine the fact that, if floors are well connected to the walls (condition mostly verified in case there are tie beams and/or dovetails and effective seams), they are able to restrain the out of plane overturning and to transfer the out of plane seismic force to the transversal walls. A proper global box behaviour occurs, in which the walls subjected to out of plane actions, being well connected to the floors, work according to a favourable scheme (either of beam or plate scheme restrained along the edges), and seismic forces are transferred to the ground through the walls parallel to them. Solid slab reinforced concrete floors may be considered rigid floors, in addition to floors constituted by brick elements and reinforced concrete joists, either cast-in-place or prefabricated, or any kind of floor with an upper concrete slab suitably reinforced and connected to all the walls (Table 6).

i. ***Types of vaults***. Is required to indicate maximum two types of vaulted horizontal structures coexistent or not in the same building, which charatacterise in the building of the typology under consideration. If detailed information is not available, at least indicate the presence/absence of vaults at the ground and/or intermediate storeys. Information about the presence of vaults at the roof level are required in Section 3.2. Examples on vaulted structures are reported in Figure 6.

i. ***Mixed structures***. If the typology in question is of a mixed type (i.e., see the coexistence of masonry and reinforced concrete or other construction types), once the previous information of Section 3.1A has been completed, it is required to specify the type of mixed structure, indicating the percentage of buildings included in typology in question. It is possible to indicate the type of mixed structure prevalent among the following: RC (or other frame structures) over masonry; masonry over RC (or other frame structures); masonry with a plan extension in RC (or other frame structures) in parallel at the same floor; Perimeter masonry walls and internal RC columns; Perimeter masonry walls and external RC columns (Figure 7); Confined masonry.

k. Mortar. Is required to indicate the main types (maximum two) of mortar, coexistent or not in the same building as well as percentage distribution which charatacterise the buildings of the typology under consideration, specifying the conditions (good, medium, bad).

l. Porch, loggia, inner court. Is required to indicate the percentage of buildings within the typology in exam and with the presence of Porches, logge, inner courts.

m. Further elements of vulnerability for the masonry. If possible, is required to indicate the percentage of buildings included in the typology with the presence of further elements of vulnerability for the masonry (lack of bonds between orthogonal wall, presence of ties beams, etc.). Vulnerability elements are grouped as follows: first 12 are related to vertical structures, the following 4 are related to horizontal structures and the connections with the vertical ones, numbers 17 and 18 relates to the foundations and the last three are related to structural irregularities.

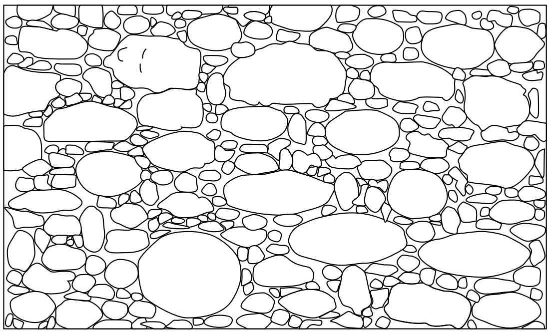
Table 1. Irregular masonry abacus (AeDES Manual).

A1: Rounded stone

Mainly constituted by smooth surface and rounded shape elements, or by small or medium size river pebbles; it may have both irregular and regular layout.

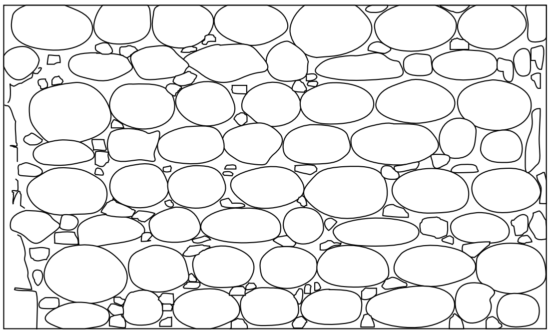
Without brick courses (S.R.)

A1.1



Senise (PZ): pebbles with irregular layout

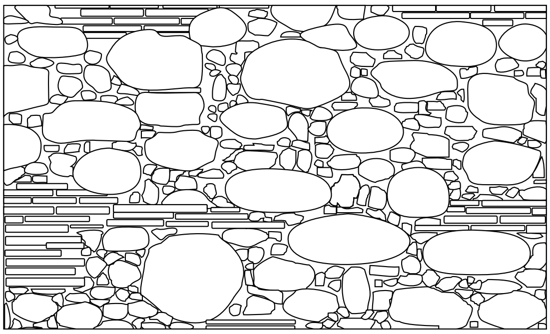
A1.2



Assisi (PG): various types of pebbles with regular layout

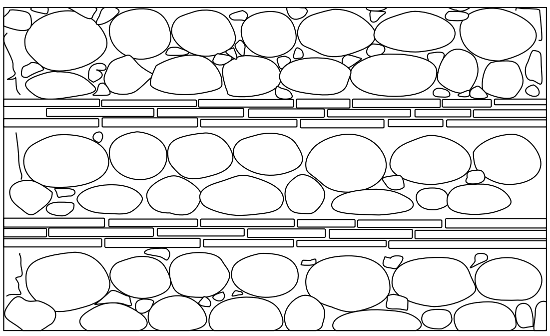
With brick courses (C.R.)

A1.3



Sassuolo (MO): pebbles and bricks

A1.4



Cast. dei Sauri (FG): Rubble stone masonry with brick courses

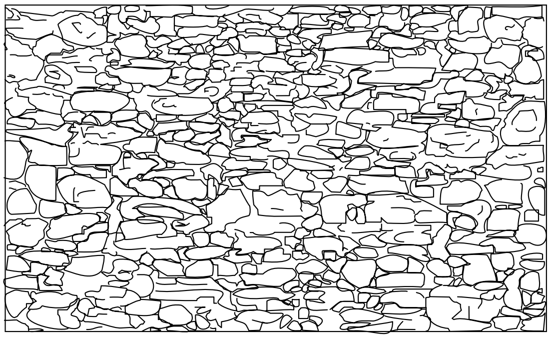
Table 2. Irregular masonry abacus (AeDES Manual).

A1: Rubble Stone

Mainly constituted by rubble stone, generally non dressed or difficult to dress: irregular shape elements of various size such as stone chips.

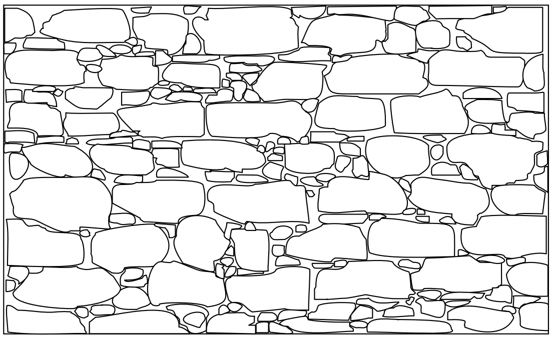
Without brick courses (S.R.)

A2.1



Benevento: rubble stone with fairly regular layout

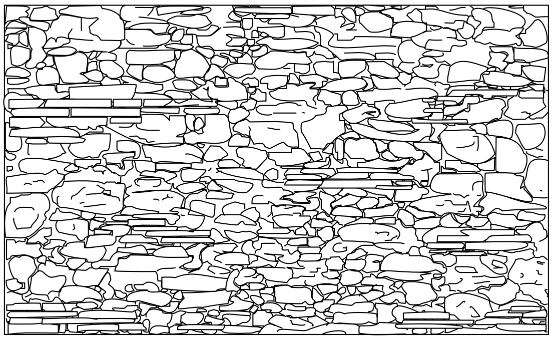
A2.2



San Angelo Limosano (CB): rubble stone with irregular layout

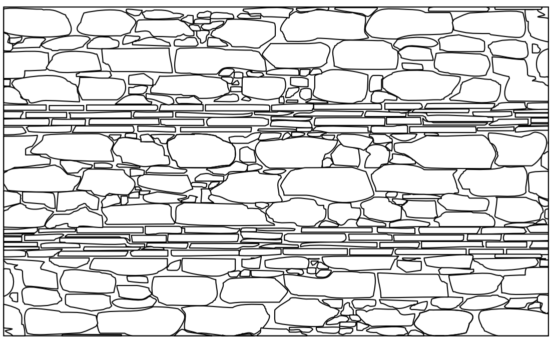
With brick courses (C.R.)

A2.3



Alia (PA): irregular masonry with flat tiles and limestone

A2.4



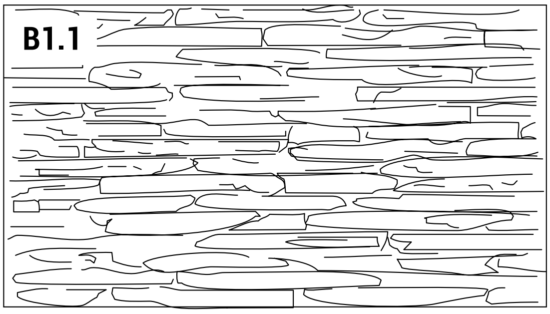
Benevento: rubble stone masonry with brick courses

Table 3. Irregular masonry abacus (AeDES Manual).

B1: Flat-cut stone

Generally constituted by semi-dressed elements, flat-cut ("a soletti" stone), obtained from low resistance stones, which tend to fracture along their horizontal plane. The semi-regular shape of the elements almost always excludes the irregular layout.

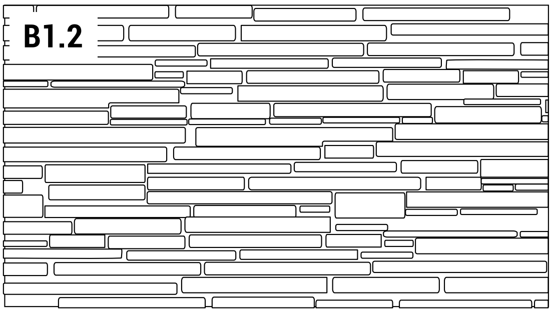
Without brick courses (S.R.)



Nocera Umbra (PG)

Picture taken from "Manuale per la riabilitazione e la ricostruzione potsismica degli edifici", Regione Umbria, ed DEI, Tipografia del Genio Civile, 1999

With brick courses (C.R.)

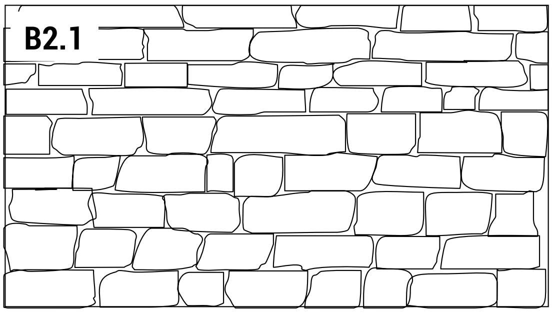


Isola del Piano (PS)

B2: Semi-regular stone

Constituted by semi-dressed almost regular stones, of larger size than the previous type. The semi-regularity of the elements excludes the irregular layout.

Without brick courses (S.R.)



Cerchiara (CS): semi-dressed calcareous stone

With brick courses (C.R.)

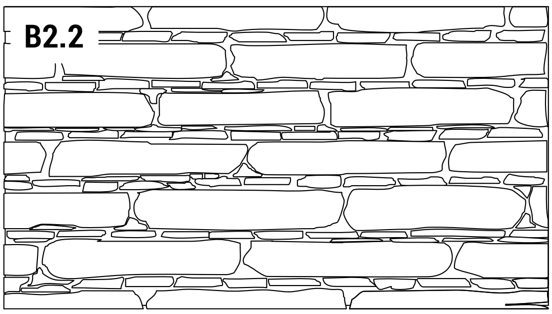
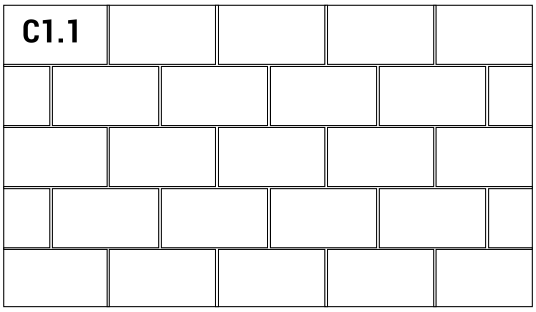


Table 4. Regular masonry abacus (AeDES Manual).

C1: Dressed rectangular stone

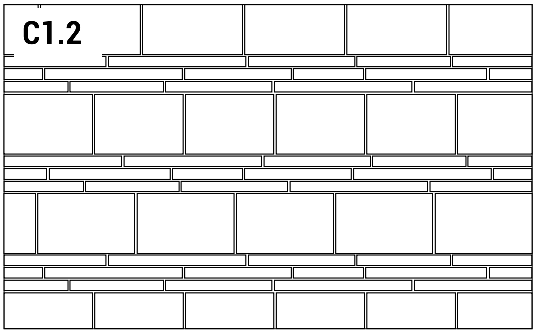
Constituted by dressed rectangular stones of predefined shape. The elements regularity excludes the irregular layout.

Without brick courses (S.R.)



Benevento: volcanic tuff

With brick courses (C.R.)

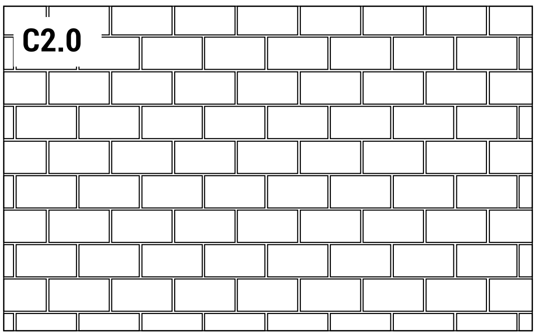


Napoli: volcanic tuff and bricks

C2: Bricks

Constituted by brick elements which due to their regularity exclude the irregular layout.

With brick courses (C.R.)

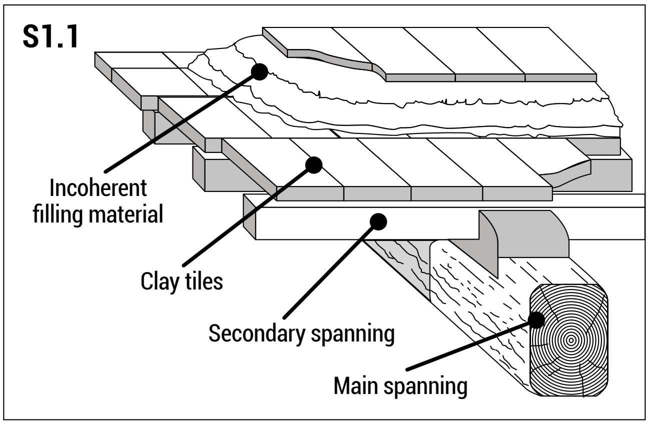


Nocera Umbre (PG)

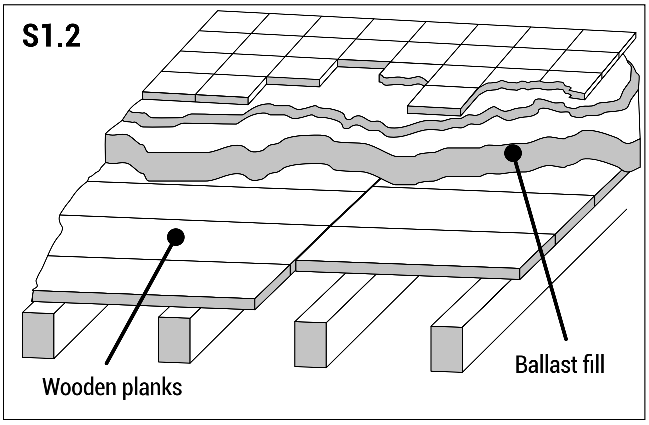
Table 5. Abacus of the flexible flat floors typologies (AeDES Manual).

4: Beams with flexible slab

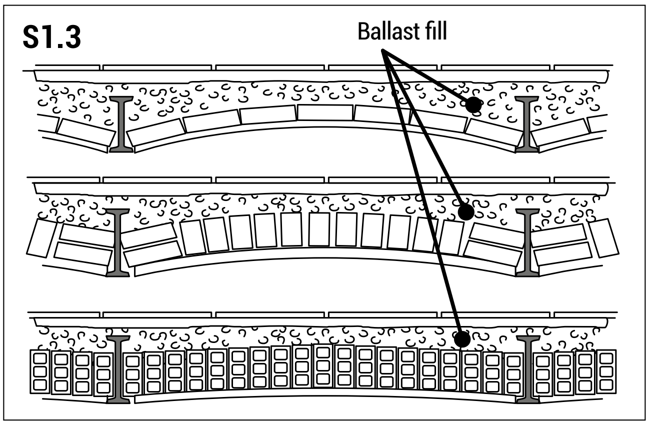
Wooden floors with single or double direction of spanning (beams and joists), with simple wood planks or brick elements (clay tiles), eventually finished with incoherent filling material or debris. Floors constituted by iron beams supporting shallow arch vaults made of bricks, stone or concrete. In both cases, if the floor has been stiffened, with two perpendicular layers of wood plank or, even better, with a reinforced slab well connected to the beams, these floors could be considered as rigid or semirigid, depending on the level of connection among elements.



Wooden floor with clay tiles



Wooden floor with wooden planks in a single direction

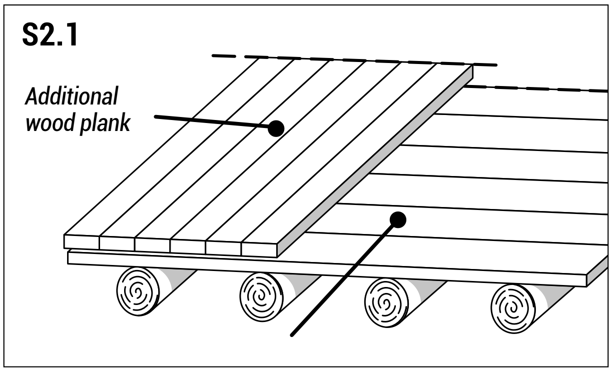


Floor with iron beams and shallow arch vaults

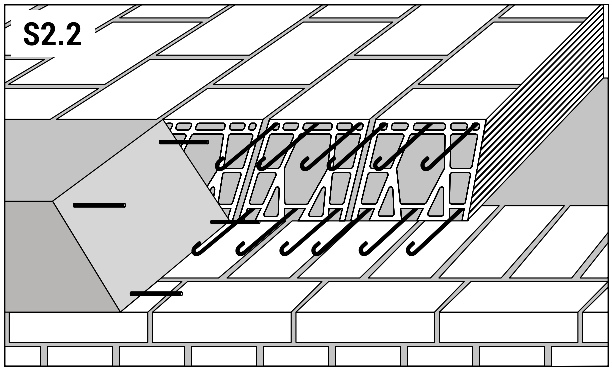
Table 6. Abacus of the rigid and semirigid flat floors typologies (AeDES Manual).

5: Beams with semirigd slab

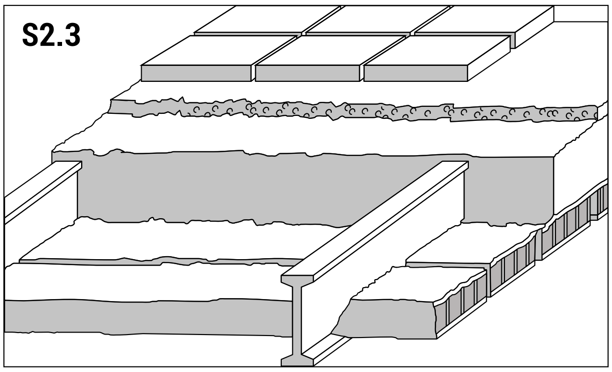
Wooden floors with two perpendicular layers of wood plank flooring, eventually finished with a reinforced concrete slab. Flat floors constituted by iron beams supporting hollow clay tiles. Floors constituted by prefabricated reinforced hollow clay tile floor beams, with reinforced concrete ring beams.



Wooden floor with two perpendicular layers of wood plank flooring.



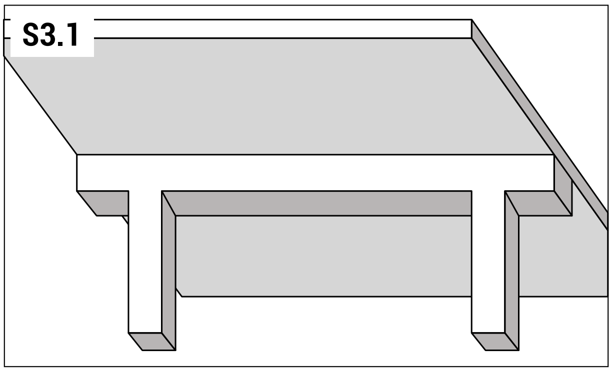
Floor made of prefabricated reinforced hollow clay tile floor beams, with reinforced concrete ring beams



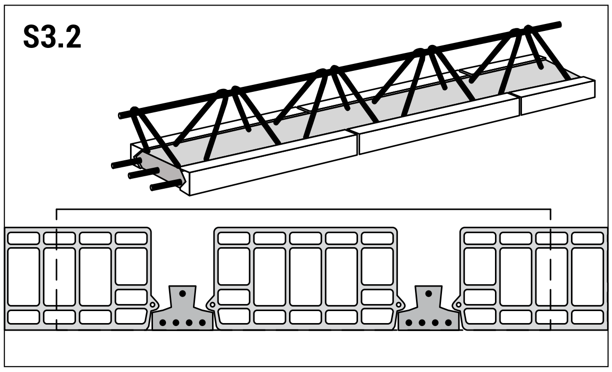
Floor made of iron beams supporting hollow clay tiles

6: Beam with rigid slab

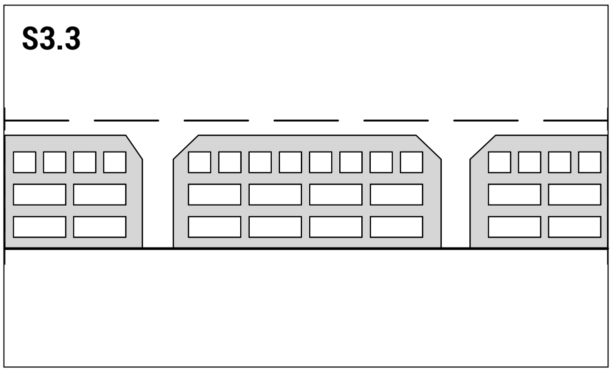
Reinforced concrete floors with solid slab. Floors constituted by reinforced concrete joists with hollow clay tiles, either cast-in-place or prefabricated.



Reinforced concrete floor with solid slab.



Reinforced concrete floor with prefabricated joists.



Floor of hollow clay tiles with cast-in-place concrete joists and topping.

Figure 6. Types of vaults.

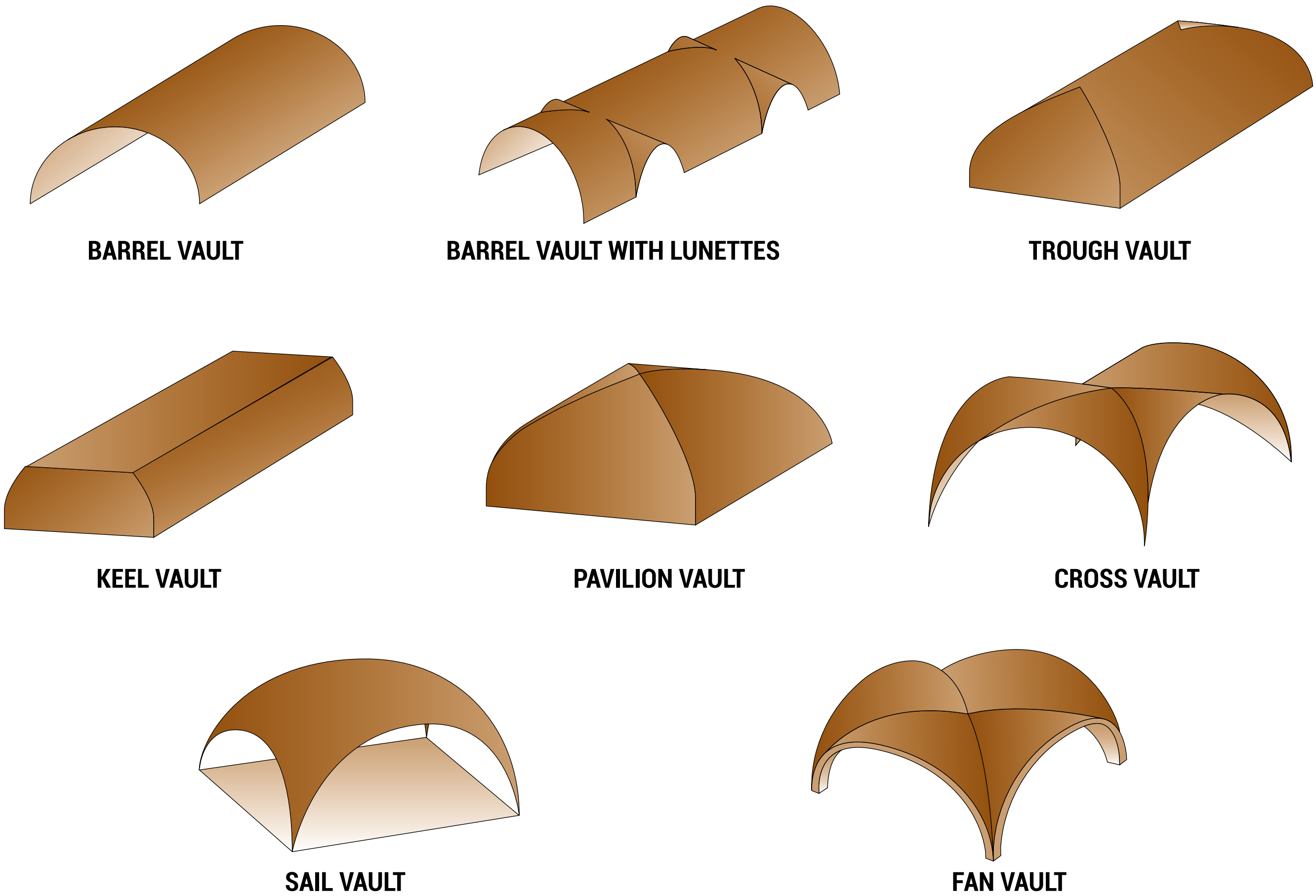
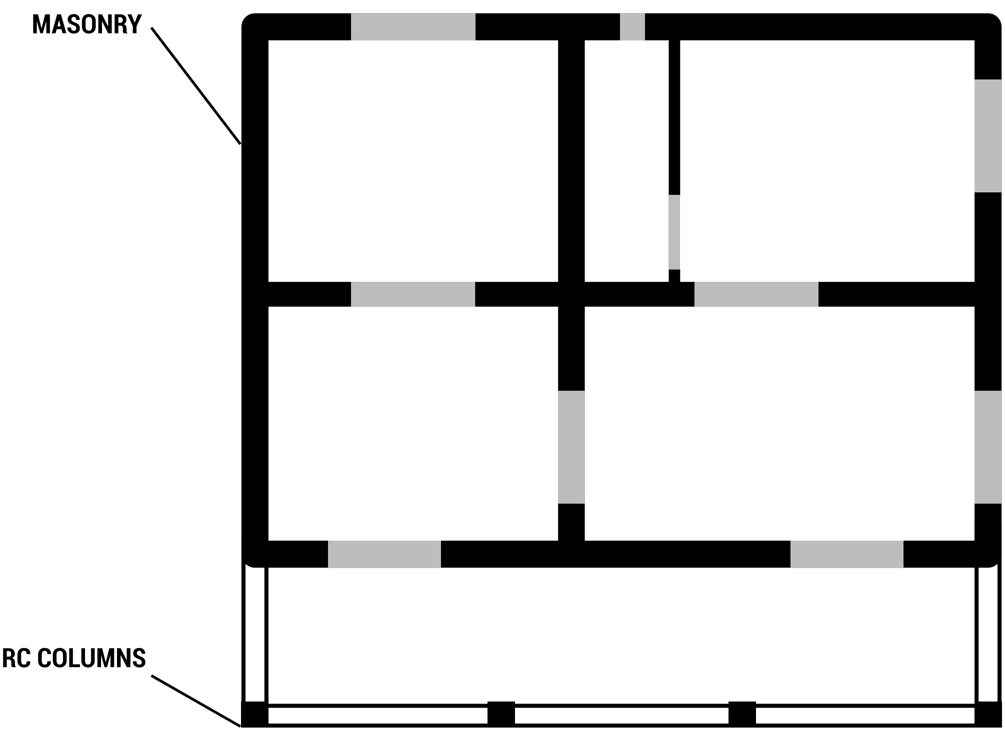


Figure 7. Example of structure with perimeter masonry walls and external RC columns.



Section 3.1B is about reinforced concrete (RC) typologies. It collects the following information:

a. Types of Reinforced Concrete structures. Is required to indicate the prevalent RC vertical structure, which charatacterises the buildings of the typology under consideration. In analogy with the forms MEDEA (2000, 2004) and AEDES (2002), the CARTIS form distinguish six types of RC structures:

- Prevalence of RC frames and solid masonry infill panels (without large openings, with resistant materials and a good layout);
- Prevalence of RC frames with spandrel beams and weak masonry infill panels (with prevalent large openings and weak materials);
- Prevalence of RC frames with flat beams and weak or absent masonry infill panels;
- Prevalence of RC frames with perimetral spandrel beams, weak or absent masonry infill panels and internal flat beams;
- Presence of both RC frames with spandrel beams and internal RC core;
- Prevalence of RC shear walls;
- Presence of both RC frames with flat beams and internal RC cores/shear walls.

b. Structural joints. Is required to indicate the percentage of building included in the typology, which are separated through standard structural joints (indicatively, it can be assumed that the standard is respected if the buildings are built after the seismic classification action and/ or if the joints have the width at least 1/100 of the height) or non-standard structural joints in the case of buildings in adjacency with a separation of a few centimeters only to allow thermal expansion, or even in contact, (even if structurally separated). As remarked in Section 1, entry c, the presence of standard joints identifies isolated building, otherwise non-standard joints refer to aggregated building which are statically dependents but dynamically independents.

c. Structural bay-windows. Is required to indicate the percentage of buildings included in the typology with the presence of structural bay-windows. A bay-window is a structural element with prominent window, even partially buffered to the building, made with a projecting structure with respect to the alignment of the columns (Figure 8).

d. One-way RC frames. Is required to indicate the percentage of buildings included in the typology, with one-way RC frames while the perpendicular direction is characterised by the absence of frames or by frames with spandrel beams (mostly perimetral). The percentage is to be indicated only in case of "YES".

e. Short elements. Is required to indicate the percentage of buildings included in the typology in consideration, with vertical short elements (due to the presence of stair beams, split levels, strip windows, etc.)

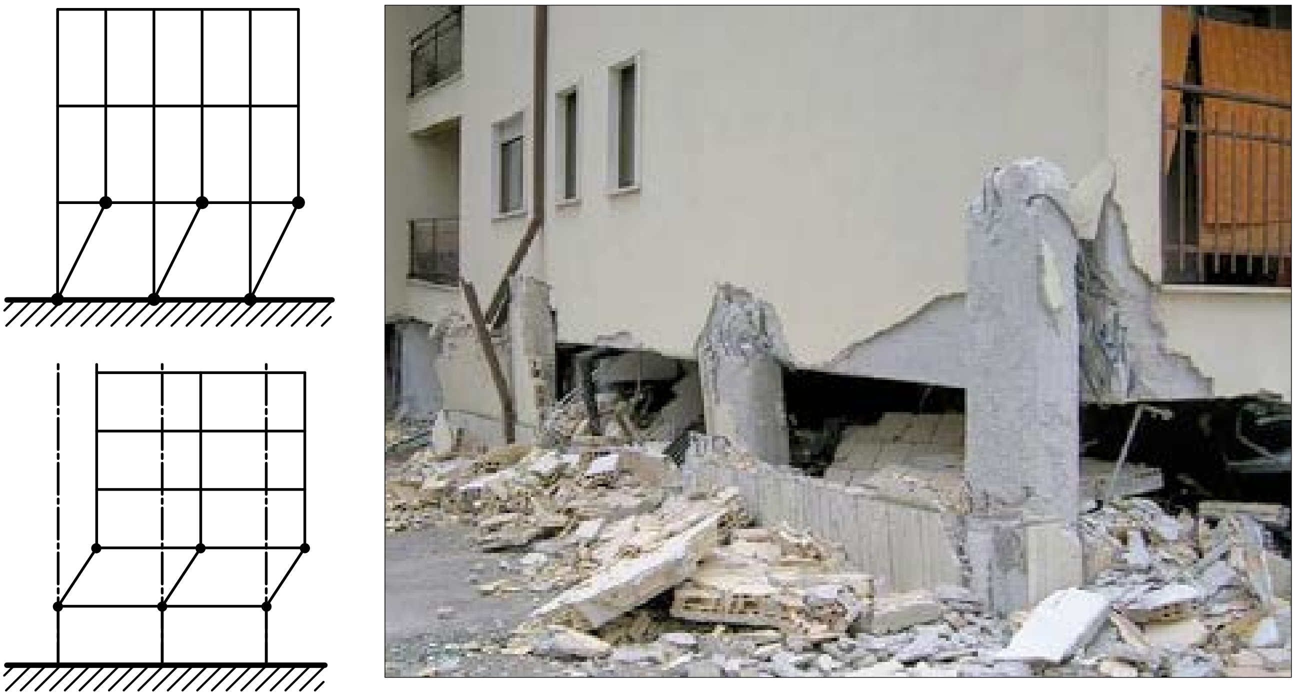
Figure 8. Example of bay windows.

f. ***Infill panels at the ground storey***. Is required to indicate the distribution of the infill panels at the ground storey (regular, irregular, absent) which charatacterises most buildings of the typology under consideration. It is important to evaluate the presence of general dissymmetry in the position of the infill panels, for instance with large openings on the street side and almost no openings on the other sides. The aim is to identify soft storeys rather than identifying generic irregularities from a bad distribution of infills at the different levels. The form offers the possibility to indicate the presence of soft storeys at intermediate levels (Figure 9).

Figure 9. Example of soft storey at the ground (a) and intermediate leveles (b).

a)

b)



g. ***Position of the infill panels in the RC frame***. Is required to indicate the position of the infill panels in the RC frame, which charatacterises most buildings of the typology under consideration. Under this entry the surveyor should evaluate the interaction and the collaboration between infill panels and RC frame, such as:

- Infill panels inside the frame: infills are totally arranged inside the structure and are able effectively interact with the RC frame;
- Infill panels outside the frame: infills are arranged externally with respect to the structure or partially and ineffectively arranged in the structure;
- Backward columns: backward columns and infill panels arranged at the end of the overhang;
- Hanging covering in front of the bearing structure– infills made of external hanging courting, continuous on the total height (Figure 10).

Figure 10. Example of dissymmetries in the infill panels (AeDES Manual).

- ***h. Columns size at the ground storey***. Is required to indicate the average size of the sections of the columns (in centimeters) at the ground storey, which charatacterises most buildings of the typology under consideration.
- ***i. Reinforcement bars in columns***. Is required to indicate metrical information on the reinforcement bars in columns, which charatacterises most buildings of the typology under consideration:
  - Longitudinal bars (percentage of the area of the bars with respect to the area of the colunn section);
  - Transverse bars span (in cm);
  - Transverse bars diameter (in mm);
  - Anchorage length (expressed with respect to the diameter of the longitudinal reinforcement);
  - Type of bar (smooth or deformed)
- ***j. Structural network***. Is required to indicate the average span between columns (in meters), which charatacterises most buildings of the typology under consideration.
- ***k. Presence of SAP floors or similar***. Is required to indicate the presence of SAP floors or similar. The SAP (acronym for "without temporary reinforcement") are a type of patented floor, with prefabricated brick and RC joists (Figure 11). The joists are prepared off-site, in the required length, with bricks of adequate thickness arranged one after the other and connected to each other by means of steel rods (at least 3) housed in special grooves in the bricks and walled with mortar cement. After curing, the joists are placed side by side and a concrete mix is cast in the interstices between the joists; often and upper slab of 2-3 cm ("caldana") is present, possibly reinforced.

Figure 11. Example of SAP floor.

Section 3.2 relates to additional information necessary for both masonry and RC typologies. It collects the following information:

a. ***Roofs***. Is required to indicate maximum two types of roofs which charatacterise at least the 80% of the buildings included in the typology.
Roofs may influence the seismic behaviour of a building in a positive or negative way, essentially through two factors: their weight and their incidental thrust on the supporting walls.
In the CARTIS form, as well as in the AeDES form, two parameters have been considered as essential, the weight and the thrusting/non thrusting character of the roof. For what concerns the weight, steel and wooden roofs are generally considered as light (unless they are covered with heavy plates or tiles, for example made of stone). Reinforced concrete roofs are generally considered as heavy.
For what concerns the thrust, the presence and/or effectiveness of the following elements must be considered: tie beam, internal wall, tie rods, rigid ridge beam, non-thrusting trusses with longitudinal joists resting on them.
Several cases that may occur are described in Table 7.
In the presence of intermediate walls on which the pitches of the roof rest, the structure is to be considered generally non-thrusting, depending on the effectiveness of the restraint that the wall offers to the joists. Additionally, the form permits to introduce information on materials (steel, wood, RC, masonry) and the shape (single-pitch, double-pitch, accessible flat roof, non-accessible flat roof, vaults).

b. ***Opening in the facade***. Is required to evaluate the percentage of openings in the facade. For masonry buildings, it would be useful, if possible, to investigate on the presence of substantial reductions in the thickness of the sub-windows walls and a consequent ineffective contribution to the overall strength of the wall. In this case, is suggested to include the inefficient sub-windows walls in the total percentage of the openings.

c. ***Regularity***. Is required to indicate the percentage distribution of irregularities in plan and elevation, which charatacterises most of the buildings included in the typology:

- shape irregularity in plan: plans not having two orthogonal axes of symmetry, (such as L, T, U, E, P shaped etc. see Figure 12); eccentric position of the staircase and/or of the elevator with respect to the axes of symmetry of the plan (Figure 12b); structural irregularities in plan, i.e. unsymmetrical or badly distributed frames, presence of re-entrant corners (with projection greater than 20% of the planimetric dimension of the building in that direction), eccentric and not uniform distribution of the dead load and of the live load, etc. (Figure 12c).
- shape irregularity in elevation: macroscopic variations of surface (± 30%) with height, creating significant overhangs or setbacks (Figure 13a), structural irregularities in elevation due to for sudden changes in elevation, more serious when the stiffness or mass passing through a plane to the upper one.

d. ***Interventions on structures in the typology***. Is required to indicate the percentage distribution of buildings which have been under interventions on structures (local interventions, seismic improvement, seismic upgrading).

e. ***Openings in the ground storey***. Is required to evaluate the percentage of openings (doors and windows) with respect to the total façade surface ad the ground storey, which charatacterises most of the buildings included in the typology.

f. ***State of Conservation***. Is required to indicate the state of conservation of the whole, vertical structures, horizontal structures, non structural elements, which characterises most of the buildings included in the typology.

g. ***Stairs***. Is required to indicate the type of stairs which charatacterises most of the buildings included in the typology.

h. ***Vulnerable non structural elements***. Is required to indicate the presence of vulnerable non structural elements, which characterises most of the buildings included in the typology.

i. ***Foundations***. Is required to indicate maximum two types of foundation which charatacterise at least the 80% of the buildings included in the typology. If detailed information is not available, indicate, if possible, the presence of shallow/deep and strip/single foundation, and the correspondent percentages.

Figure 12. Example of shape irregularities in plan (AeDES Manual).

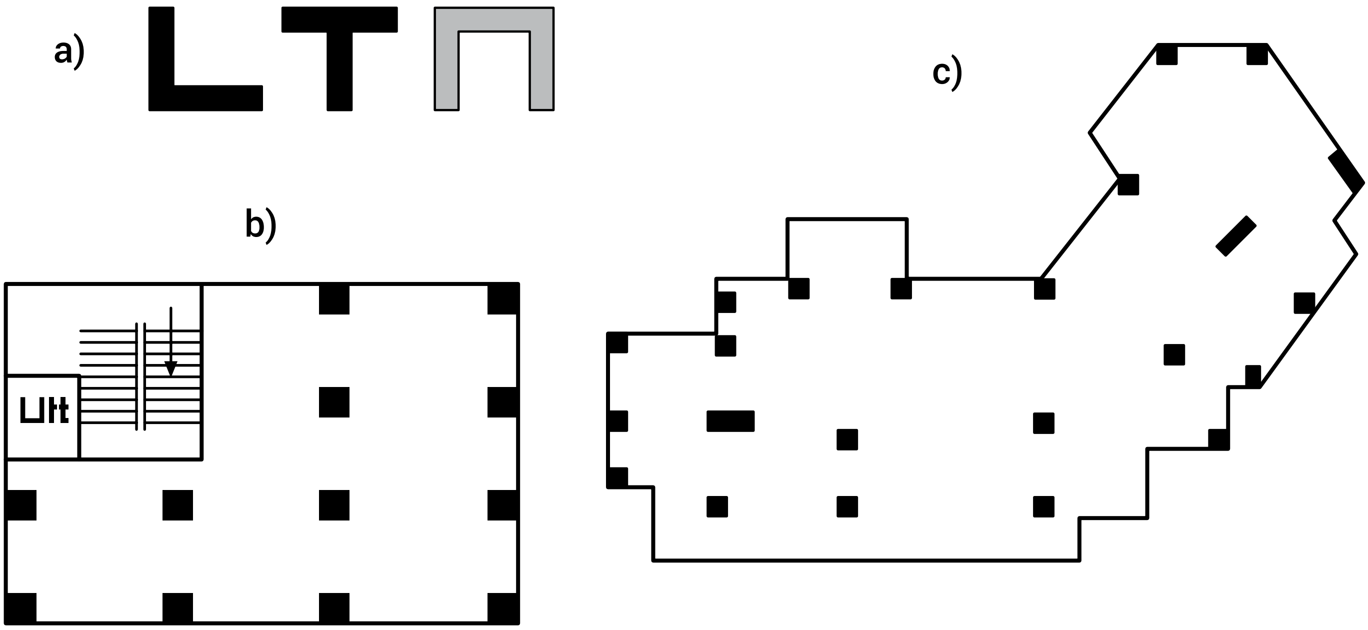


Figure 13. Example of shape irregularities in elevation (AeDES Manual).

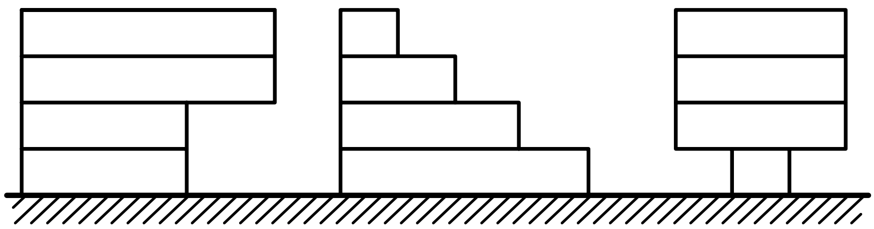
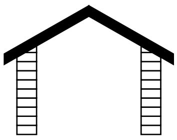
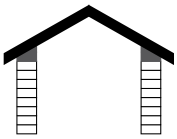
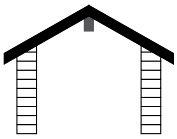
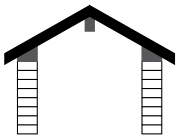
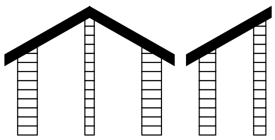
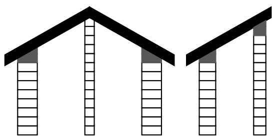
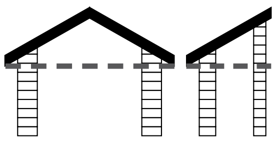
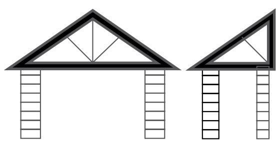
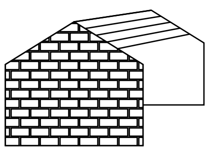


Table 7. Roofs abacus: evaluation of the thrust (AeDES Manual).

ROOF	STATIC CONFIGURATION	NOTES
thrusting	 lack of tie beam lack of internal wall lack of tie rods lack of rigid ridge beam lack of trusses	
	 presence of tie beam lack of internal wall lack of tie rods lack of rigid ridge beam lack of trusses	
Roof with thrust depending on the constraints	 lack of tie beam lack of internal wall lack of tie rods presence of rigid ridge beam lack of trusses	*The thrusting or non thrusting character of this scheme depends on the stiffness of the ridge beam. Slender beams do not allow to efficiently reduce the thrust, thus, in order to be conservative, it is suggested to consider this scheme as thrusting. However, if the rafters are well connected between each other and/or are well connected to the rigid ridge beam and to the tie beam, the roof can be considered as non thrusting.*
	 presence of tie beam lack of internal wall lack of tie rods presence of rigid ridge beam lack of trusses	
Generally non thrusting roofs	 lack of tie beam presence of internal wall lack of tie rods lack of rigid ridge beam lack of trusses	*Boundary conditions should be verified (presence of effective connections among elements), in order to be sure that beams are transmitting only vertical loads to the supporting walls.*
	 presence of tie beam presence of internal wall lack of tie rods lack of rigid ridge beam lack of trusses	
Non thrusting roofs	 lack of tie beam lack of internal wall presence of tie rods lack of rigid ridge beam lack of trusses	
	 lack of tie beam lack of internal wall lack of tie rods lack of rigid ridge beam presence of trusses	
		*Main direction of spanning longitudinal to the pitch inclination and resting on two external walls or on two non thrusting trusses*
		*Flat roof (presence of horizontal beams)*

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** NOTE pag. 7

It is important to emphasize that the identification of the prevalent typologies in each sector must be done with particular reference to the following entries, in Sections 2 and 3, considered as fundamental in the characterization of a different seismic behavior:

- Number of storeys including basements (Section 2, entry a).
- Period of construction (Section 2, entry f).
- Types of masonry (Section 3.1A, entry a).
- Types of flat floors (Section 3.1A, entry h).
- Types of vaults (Section 3.1A, entry i).
- Mixed structures (Section 3.1A, entry j).
- Types of Reinforced Concrete structures (Section 3.1B, entry a).
- Structural joints (Section 3.1B, entry b).
- One-way RC frames (Section 3.1B, entry d).
- Infill panels at the ground storey (Section 3.1B, entry f).
- Roofs (Section 3.2, entry a).
- Interventions on structures in the typology (Section 3.2, entry d).

In the form, the twelve entries listed above are marked with a thicker line box.

Developed by

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Cover
RENATO GUTTUSO
"Tetti di Bagheria" - 1984