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Wooden framed structures in Madrid domestic architecture of 17th to 19th centuries

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Structural decay in masonry buildings from the 17th to 19th centuries is very common in Madrid mainly because of poor conservation in which normally a complex pathology where cracks of different kinds appear. At present, very few studies have investigated the historical construction aspects to acquire an understanding of the morphology and the structural behaviour in order to determine the real repair needs in an intervention. This paper follows some previous ones (González and Aroca 2000; González and Aroca 2001a; González and Aroca 2001b) where there have been introduced the masonry structures and the wooden framed construction systems used in Madrid from the 17th to 19th centuries. In this one we pretend to go further in the understanding of the historical constructions which still survey in Madrid.

The starting point of this paper is related to a documental historical approach based upon the Historical Archives of Madrid. This study follows four main lines: a) investigation and selection of the most relevant contracts and documents of the 17th to 19th centuries for an individual and an altogether analysis of the evolution of the construction systems used in Madrid in that time; b) transcription of such documents; c) an individual study of the structure, methods and contents of each document, such as: people involved in works: architects, clerks of works, builders, owners, etc; and d) an altogether analysis of them with the aim of setting the origin, evolution and transformation of the construction systems used in Madrid. To a better understanding, this study will be completed with the addition of original plans, graphic construction details and the original transcription of some abstracts of the documents consulted.

Documental historical approach

As it has been introduced in the previous lines, the main point of this study is related to a documental historical approach based upon the Historical Archives of Madrid. The kinds of document consulted and transcripted is very wide, most of them belongs to two main groups: a) the documents looked up in the Archivo Histórico de Protocolos, AHP, and b) the archives consulted in the Archivo histórico de la Villa, AVS.

Contracts of works contents (AHP, Archivo Histórico De Protocolos)

The first group of documents belongs to the contracts of works, and among them are included: 1) new houses construction contracts, 2) rebuilt houses contracts, 3) repairing contracts, 4) houses division documents, 5) titles deeds, 6) expert valuation of houses, and 7) renting contracts. Those from which we can take out a more detailed information are the real contracts of works. As architects, clerks of

works, builders, owners and other people involved in works were not compelled to sign a contract of work including: work conditions, material prices, paying conditions, etc, there are only conserved some of them. Works in Madrid were usually carryed out following a house building tradition.

The contents of the documentes consulted in the Archivo Histórico de Protocolos, AHP, include the original documentation of contemporary domestic architecture built in Madrid, that is: a) written information, and b) graphic information. A general approach to the first one can be seen in the next lines that belong to an expert valuation of a house where there are analysed, in the first lines, the fonctional distribution of rooms containing a cellar, courtyard attics, different rooms, main floor, etc, and in the next ones, the different construction systems employed in the foundations, façades, internal walls, partywalls, floors, roof, and finally the price of the expert valuation

> . . . Un sottano, pattio y desbanes, y enzima de dicho quartto principal y caja de escalera, tres quarttos ô viviendas de dos piezas cada uno. Todo lo que estta fabricado de zimientos de mampostteria, vaciados de tierra, cantteria en la fachada principal. Una porttada moldada, de jambas, denttel y battientte, con su cornisa enzima, y la de el pozo sus dos hiladas de canteria y lo resttante de fabrica de albañileria, y la fachada de la calle de la Cueva, de mâchos y cajones de tierra y en lo intterior fabrica de albañileria y machos de lo mismo, tapias de tierra, zittaras, tabiquess, suelos de bôbedillas, de ttodos tamaños, con solados de ladrillo y de yesso. Armaduras, aleros y guardillas con su tabla y teja, canelones de plomo, y de ôja de latta, puerttas y venttanas con sus herragess y rejas, balcones, ânttepechos y barandas de fierro. Solados de barroqueña y canales de lo mismo, pozo con brocal de cantteria, cuevas, sottanos, empedrados, medianerias, pesebres y lo demas de que se compone lo referido, lo tassó, ttodo que vale. Segun âl presentte se halla, sittio y fabrica, cientto y ôchentta y nueve mill trecienttos, sesentta y zinco Reales de Vellon . . . AHP. N1 16.366 (1741). Expert valuation of a house.

and, in the graphic information we will see the elevations of the façades and floor plans, sometimes displaying the functional distribution of rooms, and often including a graphic scale, nearly always refered to castillian feet. In the figure 1 we show a contemporary document.

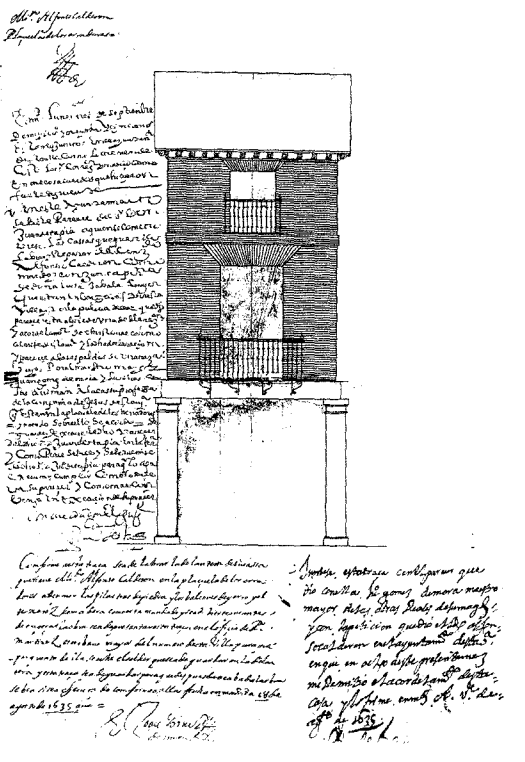

Figure 1
House built in Madrid in 1635. Contract of work. AHP Nº 2.692

«Works licences application» (AVS, Archivo de la Villa Secretaria)

In the second group of the documents consulted we find the «works licence applications» which were compulsory to be approved by the local government before starting and carrying out the houses construction. These documents should include the elevation of the façades and a general written information about the work conditions. Optionnally added a wide graphic information, such as, the different floor plans with the explanation of the fonctional distribution of rooms and very rarely cross sections. In this second group of documents the most significant information is connected to the graphic information because, in practice, the reduced lines of the work conditions were a mere procedure to obtein the «contruction licence». In the figure 2 is shown this kind of document.

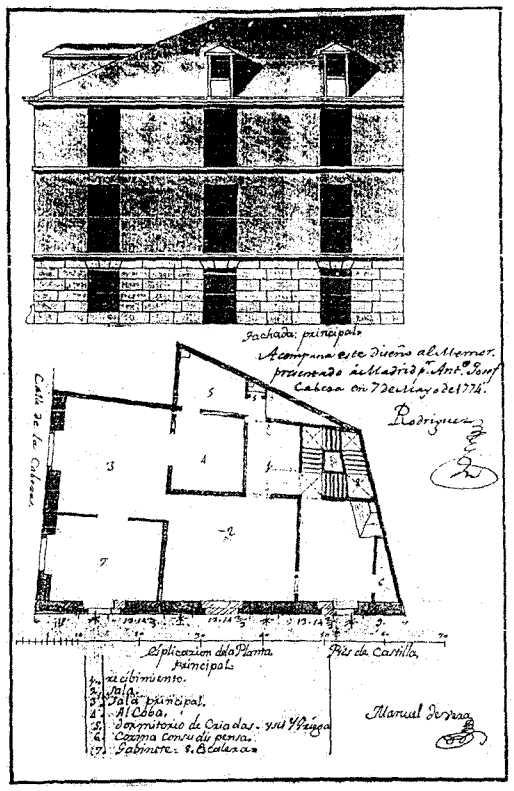

Figure 2
House built in Madrid in 1774. «Works licence application». AVS (1–48–10)

This paper presents a chronological historical approach using contemporary systems of measurement, typically castillian feet which were of an aproximately length of 28cm and castillian finger of around 1.74cm. This unity system was employed at least since the 16th century and it was not substituted until the end of the 19th century, when the international unity system, as we will see later on, mostly meters and centimetres, was generally introduced in construction systems. As mentioned in the previous lines, the attention will be focused on the documents contents, that is, the chronological approach following the date of the documents, the emplacement, work conditions and people involved in them, graphic information with the scale, and written information explaining the construction systems including the prices of the materials.

Construction systems: A general approach

The documental historical approach reveals a considerable information about the way of building houses that it can be hardly seen in the existing bibliography. The construction consisted of a structural wood framework both vertical and horizontal, usually called «entramado» placed over a foundation and a ground floor built both totally with masonry (brickwork or rough masonry work) and sometimes built also with stonework. Over it, there were placed a wood structural framework from the main floor or «cuarto principal» until the roof. The basic criterium to build them lyed in the width of the «carrera», that is, the beam placed horizontally in the walls, and from it they dimensioned the rest of the wood structural elements, decreasing in width as the house grew higher. The spaces left between the vertical and horizontal wood elements in walls (main walls, secondary walls, partywalls, etc) were filled with different materials, such as bricks, rough masonry work, sun-dried bricks, etc, and the spaces left between the horizontal wood structural elements in floors, with decreasing sections depending on the spans, were also solved with masonry.

This historical constructions systems made of wood were pecfectly regulated and controlled by the local government at least from the 17th century, and later on were slowly being substituted by masonry work as most by-laws of that time reflected. In many documents of the 18th century there are references about it but, in none of them, we have found that these new circumstances could make compulsory to build the houses only with brick. In the second half of the 19th century, it comence to appear certain concrete rules about this subject. The starting point of this subtitution process lies in the vertically structure, to be exact, in the main walls or façades which were the first ones built totally with brick. In what concerns the wood horizontal structures, it has to be pointed out that it was not until the end of the 19th century when they started being substituted by steel beams.

The main part of this paper, once advanced a general approach to the historical archives, is related to the study of the construction systems employed in Madrid domestic architecture of 17th to 19th centuries throughout the original documents. This study follows two lines: 1) the masonry construction systems and 2) the mixed structures, that is, the construction systems built of a wood structure and a masonry filling work.

Masonry construction systems

This part will analyse masonry structures built in Madrid in the 17th–19th centuries: 1) foundations; 2) caves; and 3) masonry walls including: a) main walls, b) «cítaras» or thin walls, c) party-walls and, d) partitions. To a better understanding of the written information analysed, we will bring to the most relevant abstracts of the documents transcribed in each section.

Foundations

The construction of foundations, as most contracts and records of works in the historical archives mentioned, always were a concern in the construction process. To classify the foundation types, we can analyse: dimensions, (depth, width, the length was determined by the length of main walls) laying foundation works, stages of filling the foundations, materials, etc. They were built in two different ways: 1) «Foundations with "zanja corrida" or a trench which was then filled with a mixture of stones and mortar placing the biggest ones at the bottom in different courses separated by two lines of bricks, and 2) foundations by "masonry-filled" pits and arches of stone or brick on the top». This second method was used when the site to lay the foundations was filled with demolished materials or whether there was some element that needed to be overpassed, also water conductions. A typical foundation built in the domestic architecture in Madrid in 17th to 19th centuries is shown in figure 3.

We have made a selection of three abstracts, one of each century, explaining these construction systems mentioned above

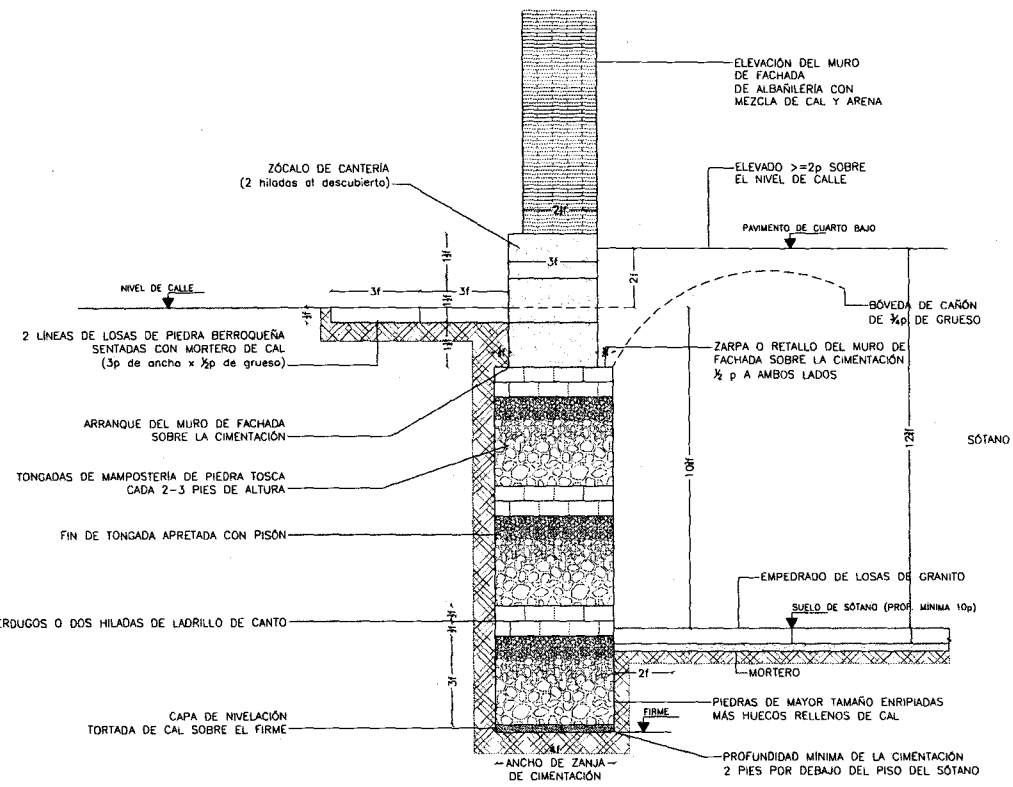

Figure 3
Typical foundation built in the domestic architecture in Madrid in 17th to 19th centuries

. . . que se a de abrir zanjas hasta lo firme medio pie mas anchas para rodapie que esto es mas ancho de lo que demuestra la planta y las a de maciçar con la mezla de cal dicha y areposada y de piedra de las canteras de San Ysidro y a de recivir toda la piedra que saliere de los redinos dejandolas a nibel del suelo o lladero quatro dedos mas baxas para el asiento de sillares y para elijir la mampostería. Que en el patio y patinejo a de sentar un sillar alrededor de media bara de lecho y media bara de alto y a esta altura, an de quedar todos los cimientos adbirtiendo que en el paño de la cavallerica los que caen del los a de labrar por de fuera con piedra pedernal de la marjen y por de dentro como los de demas los a de enrassar y enrassados todos a nibel y encima a de elegir verdugos y pilares adbirtiendo que el patio y patinejo y lo que falta de elejir en la calle todo a de ser de albañilería . . . Contract of work of a house built in C/ San Miguel. AHP N1 10.849 (1669).

. . . Se ha de vaziar el vano de los sotanos y gruessos de paredes a la profundidad de diez pies y quarto desde el pisso de la calle continuando las zanjas de otras paredes con un pie de zarpa exteriormente, y en lo ynterior, medio pie que es una de zócalo al cuerpo del cuarto vajo, y dos pies mas profundo que el pavimento de otros. Que hallado el firme y puesto à nibel se haian de mazizar las zanjas con mampostería vien travada de buena piedra pedernal, con su mezcla de cal correspondiente enrrassando de tres en tres pies y hechando à cada enrrasse sus dos yladas de canto de ladrillo de la mejor calidad levantando las paredes en la misma conformadas excepto la que hunde los dos sotanos que ha de ser de buena fábrica de alvañilería . . . AVS. 1–46–3 (1747).

. . . Los cimientos han de construirse de piedra pedernal con mezcla de cal y arena; sobre terreno firme, dándole cuatro pies de grueso hasta medio pie mas bajo que el nivel del piso de la calle, en donde retallándose medio pie de cada lado se sentará el zócalo de cantería de tres pies de altura lo menos con su tizon correspondiente, resultando dos hiladas descubiertas en el punto más elevado de la calle, continuando á nivel hasta el mas bajo, sin que falten estos en ningun punto de la fachada . . . AVS 1–114–26 (1838).

Cellars

Historical houses built in Madrid, principally those placed in main streets, often had stores in the ground floor and cellars or undergrounds under them. They were masonry walls built only with brick or with «mampostería» around 3.0–4.0 feet width (84 cm) and then covered with brick vaults with the bricks placed radially so they made the floors of the above stores. Both were comunicated by staircases or even provisional stairs. In general they were only built in the first «crujía» facing the main façade where they placed windows, also called «lumbreras» or «troneras» to light and ventilate the cellars.

En las tres tiendas, se pondran dos peldaños en la entrada de cada una de piedra con sus troneras para la luz, y ventilazion de los sotanos, y en ellas se pondran tres postigos nuebos enrrasados de ordinario, con un quarteron en cada uno con su varilla envevida, y el tercero peldaño de ellas, sera la peana del cerco . . . AHP N1 16.455 (1760).

Masonry walls: analysis of the structural composition

One of the main parts of this paper is related to the construction of historical masonry walls, that is, the vertical structural organisation of Madrid domestic architecture. As we will see along this part of the study, they were built with masonry, consisting of brick work only, or by mixing a vertical and a horizontal structure of wood and filling the spaces between them with rough masonry. The foundations were built to a height of 1.5–4.0 feet over the street level and were leveled with mortar, so that the walls defining the general vertical structure could be built above. From the very early documents the construction of walls, although very shematic in the first ones analysed, is mentioned. As we can see next in a document from the early years of the 17th centuries, although very scant in its graphic plan, reveals a quite detailed written information, about: material prices, masonry works, wood structural elements employed, etc, if compared with those of the same period of time. In the figure 4 is shown a contract of work of a house built in Madrid in 1636.

Primeramente cada tapia de manpostería de piedra de Caramanchel de cinquenta pies quadrados por prezio de quarenta y seis reales. Cada tapia de zitara vista de albañileria cuadrado por prezio de 60 maravedies. Cada pie de tavique de forja de todos los que vubiere en la obra 30 maravedies. Cada tapia de jaarro de zinquenta pies superfiziales por onze reales. Cada tapia de solado de zinquenta pies superfiziales por diez reales. Cada tapia de blanqueo a toda costa azeite yeso y paños por tres vellones y medio . . . N1 7055 (1636). Contract of work.

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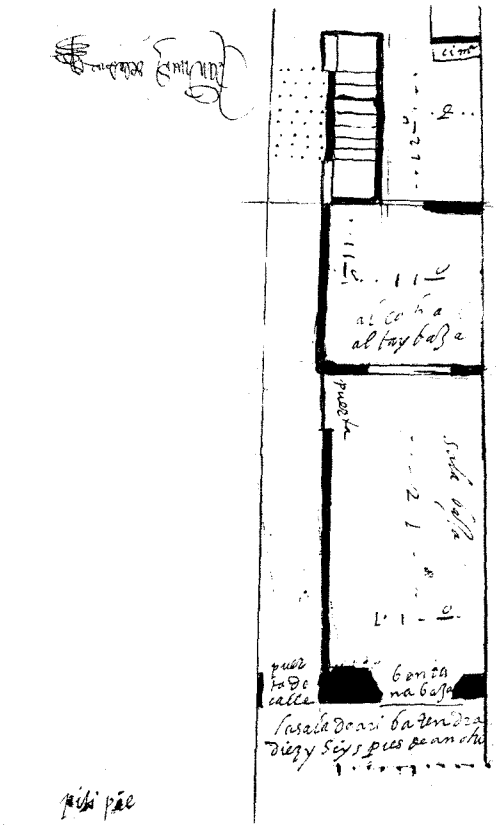

Figure 4
House built in Madrid in 1636. Contract of work, AHP. N1 7055

Masonry walls can be classified in four groups: 1) main walls, 2) «traviesa», thin or secondary walls, 3) party-walls, all structural walls, and 4) partitions, with no structural function but only a partition role.

1) Thick walls, main walls or façade walls:

The main walls were built in the main «crujías», that is, they were located in the main façades, in the internal walls following the direction of façades and in the interior court walls. Historically façades in Madrid were mainly built in two different ways: 1) Structural wood-framed walls which were traditionally built from 17th to the middle of the 19th century that will be studied in the next section, and 2) masonry façades walls which were built along these three centuries but, from the mid-19th century until today the exclusive ones. These walls were mainly built in two different ways: a) with a brickwork using bricks of (1 foot × 3/4 foot × 2 fingers), (3/4 foot × 3/4 foot × 2 fingers) and (1/2 foot × 3/4 foot × 2 fingers) and a mortar of lime and sand making a resultant width of (3.0, 2 3/4, 2 1/2, 2 1/4) feet (63–84 cm), and b) with masonry pillars and brick courses and filling them with rough masonry filling with a resultant width of (2 1/2–2) feet. Both of them were then finished wether as masonry exposed, as it is shown in figure 5, or with an external mortar and over it a madrilennian revoque. These main structural walls usually decreased in section as the façade wall grew higher. As it can be seen next, the wall inicial width was 3.0 feet and this section was reduced a quarter of a foot each upper floor until the last one which had 2 1/2 feet width.

> sobre el referido zócalo y con el mismo grueso de tres pies seguirá de fábrica de ladrillo y mezcla de cal y arena el cuerpo bajo hasta la imposta del piso principal y de la misma fabrica en todas sus alturas, siendo los arcos de puertas y ventanas del propio material sin entramado alguno ni humbrales de madera, retallándose un cuarto de pie por lo interior de cada piso de los siguientes, de forma que resulte el último de dos pies y medio para el asiento del alero . . . AVS 1–114–26 (1838).

In the next house repairing contract they alert not to demolish these main walls and neither to open a recess in it, excepting the external doors for the stores built at street level.

> Que en dicho reparo y obra nueva no se â de hazer rompimiento ni derribo en las Paredes Maestras de las dos ligneas ynterior ni esterior de circunvalacion de angulo agudo que forma la dicha casa escepto la abertura de las dos puertas para las tiendas y rejas de los entresuelos quedando firme el zimiento en la fondometria. Que dicha obra segun su plan â de empezar por la altimetria para quedar defendida antes que rompan las aguas ynvernizas. Que asta estar concluida la primer obra de la altimetria no se á de hazer derribos ni rompimientos para la segunda y tercera en los descensos . . . House repairing contract. AHP N1 16.968 (1745).

Madrid by-laws obliged to keep certain measurements for the balcons depending on the street they faced and the heigth of the floor, that is,

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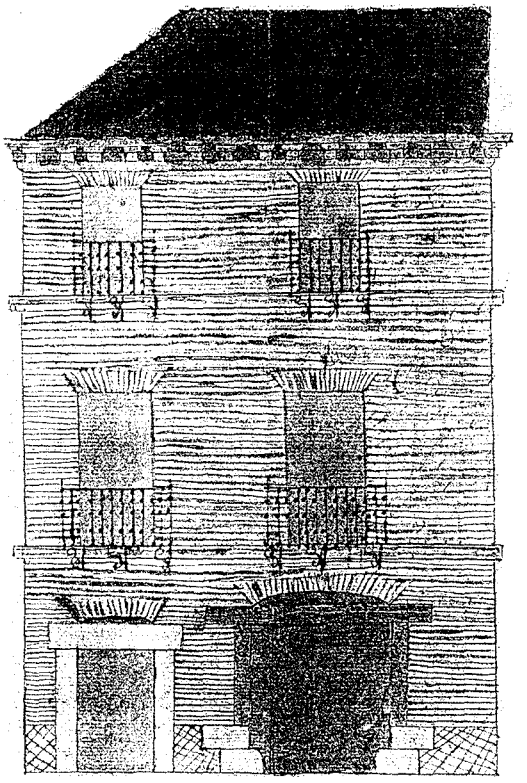

Figure 5
House built in Madrid in 1692 in masonry left exposed. AVS 1–10–44

decreasing from 1.50 feet in the main floor to only 0.50 in the third floor; they also regulated the doors at street level, the sidewalks and the finish work in the façades. The next abstract of a 19th century document refers to it.

> Los balcones en el caso de ser voladizos tendrán lo mas pie y medio los del piso principal, uno los del segundo, y medio los del tercero, dandoles de altura tres pies y tres cuartos, y el intervalo de los balaustres seis dedos, dejando recibidos las patillas en el grueso de la pared un pie, y mas de otro separados del vivo de la luz de las ventanas. En las puertas no habrá batiente ni peldaño que salga del filo esterior de las fachadas, para que no impidan el tránsito público, debiendo abrir aquellas hacia lo interior de la posesion. En la acera se sentarán losas de piedra berroqueña de medio pie de grueso y cuatro de salida, ciñéndola con el empedrado, labrada toda á moda con punta tirada bajo de un arrasante y sentada con mortero de cal, sin que en ellas puedan abrirse lumbreras orizontales á los sótanos, debiendo colocarse estas en las mochetas de las puertas, ó verticales á los demás huecos de ventanas; y por último se rebocarán las fachadas decentemente con arreglo á un buen orden de construcción . . . AVS 1–114–26 (1838)

2) Thin walls, «cítaras» or «tabicones»

This second part of the classification of masonry structural walls built in Madrid houses of the 17th to the 19th centuries, also called «cítaras» or «tabicones» (or thick partitions), «were secondary or «traviesa» walls that cut main walls perpendicularly. They had a width of 3/4–1 foot (21–28 cm) and were located in interior court walls, interior walls and staircases. As in the preceeding section, they were built in two different ways, that is: 1) thin walls, «cítaras» or «tabicones» made with a wooden vertical and horizontal structure and filled with masonry work which will be studied in the next section, and 2) masonry thin walls. This second way of building the «cítaras» where, in general, the resultant width of the wall dependant on the position of bricks. The bricks most commonly used were those of (1f × 3/4f × 2 fg), (3/4f × 3/4f × 2 fg) and (2 f × 3/4f × 2 fg).

3) Party-walls

The main structural fonction of the party-walls was the lateral or back separation of neighbouring houses. They had a width of 3/4–1 foot (21–28 cm). Clerks of works used to build them perpendicular to main walls and to the rear of houses. As mentioned previously, the historical presence of party-walls was also registered in the different contracts of works, records and by-laws in Madrid. After the great fire of the Plaza Mayor de Madrid took place in 1790, Villanueva asked the local government of Madrid to outlaw building partywalls with wood and to encourage raising them only in brick. At the end of 19th century and in the construction of new zones of Madrid, Madrid laws stipulated that at least every third house should have a partywall made totally with brickwork, rising at least a metre over the highest part of the roof. Nonetheless this was not always respected. As with the main walls discussed previously, the vertical section of masonry party walls also decreased with height, being reduced by

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around 1/4 feet in width at each floor. In this way party-walls had a typical width of 3.25 feet at the ground floor, 3.0 feet at the main floor, and so on until the roof.

4) Partitions

As mentioned before, partitions, the fourth group of masonry walls studied in this paper, divided the floors into usable spaces and did not have a structural function. From a structural point of view, they were held up by the wooden walls and were therefore built as thin as possible to reduce their weight. They were built in two different ways and their thickness varied in each case: 1) wood framework partitions filled with masonry, analysed in the next section, and 2) Masonry partitions built as follows: a) principal partitions or («tabicón»), in which the bricks were placed horizontally and had 1 foot (28 cm) width, b) double partition or («sordo») with two lines of bricks placed vertically and with a width of more than $^1/_2$ foot (8 fingers or 14 cm), and c) simple partitions or («panderete») with one line of bricks placed vertically and 4–8 fingers (7–14 cm) width. All these masonry walls studied in the previous lines can be seen in figure 6.

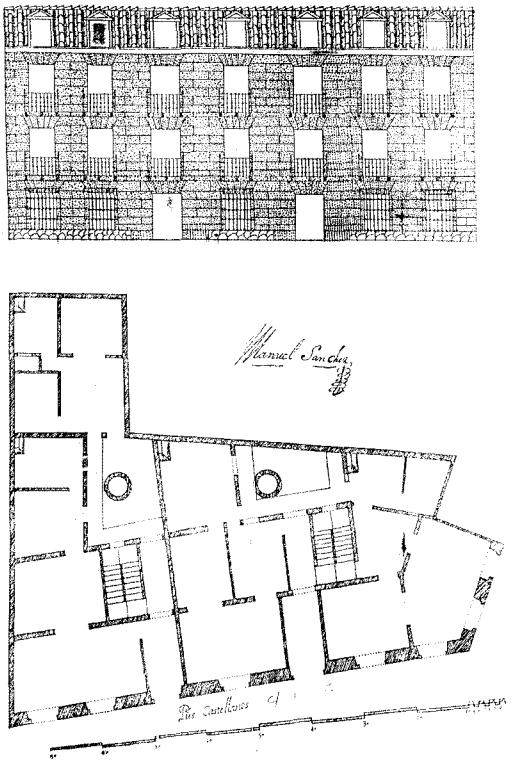

Figure 6
Masonry walls. AVS (1–84–16) 1742

Timber construction systems: structural organization

In some previous papers have been fully detailed written and graphically the most commun contructive systems employed in Madrid domestic architecture from 17th to 19th centuries. In the next lines we will try to make a general revision of the main timber structural organization of this kind of buildings for a later better understanding of the documents analysed.

Timber elements

As it has been mentioned before, timber framed historical constructions were built with a wood structural frame (vertical and horizontal) and with a rough masonry filling. The most common wood elements employed in Madrid in 17th–19th centuries were named according to their measures (length, width, height) and price (Ardemans, 1719). They are classified in separate groups according to the role they played in construction systems: 1) timber structural elements (used whether vertically or horizontally): beams, small beams or «viguetas» and «maderos», they were employed to build the main structure of walls, floors and roofs and they are classified according to the names and main dimensions ordered as the section and length proportionally decreases in Table 1 and 2) non-structural timber elements: «rastreles» and planks mainly used to cover floors and roofs, they can be considered as a third and fourth wooden level in domestic construction systems used in Madrid. As in the previous table, they are classified according to their dimensions (length, width and height) in Table 2. These wood elements, structural and non-structural, were mostly joined with nails of different types according to their lengths.

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Table 1
Timber structural elements

	NAME	DIMENSIONS Length (feet)	Height (feet/fg)	Width (feet/fg)	
BEAMS	Half vara beam	< 30 > 30	1 ½ feet	1	
	Foot and a quarter beam	< 30 > 30	1 1/4 feet	1	
	One third by one fourth beam	< 30 > 38	1feet	3/4	
	One fourth by one sixth beam	22-30 > 30	3/4 feet	½	
	22-feet 'vigueta'	22	3/4	½	
	Half 'vigueta' (12 f)	12			
MADEROS	Madero of a 6	18	11 ½ fg	8 fg	
	Madero of a 8	16	9 fg	7 fg	
	Madero of a 10 double	14	7fg	5 fg	

Table 2
Timber non-structural elements

	NAME		DIMENSIONS Length (Feet)	Width (Fingers)	Height (Fingers)	
RASTREL	'Alfargía' of 12 feet		12	5	7	
	'Alfargía' of 9 feet		9			
PLANKS	'Tablón'		-	3	-	
	14 feet	Gordo's plank	14	18	2 1/2	
	9 feet		9			
	7 feet		7			
	12 feet portada's plank		12	24	2	
	14 feet	Chilla's plank	14	16	2	
	9 feet		9			
	7 feet		7			
	Ripia's plank		4	8/3	4 lines	

As we can see in the next abstract from the early years of the 17th centuries, in the contracts of works all these wood elements were perfectly typified following the tables previously shown.

Cada bigeta de beinte y tres asta beinte y cuatro que es lo que a de llevar la sala baja y alta y esto se entiende cargando en el pilar de la medianería con su bobedilla acabada en toda perfezion por precio de quarenta y quatros. Cada madero de a seis de la misma manera rematado por prezio de veinte y ocho reales. Cada madero de a ocho de la misma manera rematado y que tenga desde doze pies arriba sin no los tubiere rezudiendolos a ellos por veinte reales. Cada pie de viga de terzia y quarta labrado y sentado por tres reales y medio. Cada pie de viga de quarta y sesma labrado y sentado por sesenta maravedies. Cada viga de tejado que sera de quarta y sesma con bentaja toscas sentadas por prezio de treinta reales. Cada tabla de una quarta de ancho clabada por sesenta maravedis. Cada tramo de madera de a seis cuatro al tramo entablado con tablas de carreta por prezio de beinte y dos reales que es cada tramo ocho ducados. Cada tramo de madera de a ocho cinco al tramo entablado de la misma tabla cada madero de doze reales que es cada tramo sesenta reales. Cada peldaño de escalera de una bara de grueso perdidas las zancas y mesillas por prezio de catorze reales . . . Contract of work. AHP N1 7055 (1636).

The elevation of the neccesary provisional structure to build the house, the scaffolfs, were also registred in some contracts of works indicating the main sections of the wood elements, the way of placing them, and also some instruccions to follow, such as not to leave too many bricks on them, to prevent possible accidents

. . . En la construcción de andamios de las fachadas de esta casa, se observará que las almas sean de sesmas colocadas en medio de los huecos, á escepcion de las de los estremos que estarán á la línea de los muros medianeros para que por este medio no resulten mechinales en la fábrica; los puentes serán de maderos de á seis y los tablones de buena calidad, sin nudos saltadizos, poniendo tres por lo menos en el ancho de cada andamiada, no consintiendo el Arquitecto se carguen con mucho ladrillo, y para evitar todo motivo de desgracia, se pondrán maderos de á ocho ú de á diez entre las almas que sirvan de antepecho ú barandillas; elevados de los tablones cuatro pies menos cuarto; redoblando este cuidado en donde se coloque el pescante, el que será formado con toda solidez, y los andamios interiores cuidará el profesor se hagan segun arte, con la idea de precaver la ocurrencia de una desgracia. AVS 1-114-26 (1838).

Construction systems built with timber

The main constructive systems built with timber in the domestic architecture of 17th–19th centuries in

Madrid were: 1) timber walls, 2) wooden floors, and 3) wooden roofs.

1) Timber walls

This section of the domestic architecture of 17th–19th centuries of Madrid is separated in five groups: 1) main walls, 2) «traviesa», thin or secondary walls, 3) party-walls, all of them structural walls, 4) partitions (no structural function), and 5) «corralas» or corridor houses. As it has been said in the previous section, walls were not only built with masonry but also with a mixed structure.

- Timber-framed façade walls. Madrid façade walls from the 17th century until the end of the 18th century were built with a timber frame which supported wood and masonry floors, and was filled with brick, rubble, plaster, adobe, etc. They were built on a masonry first level (ground or store floor). This constructive system continued from the main floor until the roof. Then the façades could be left exposed or covered with a finish of mortar and plaster, or «madrilenian revoque». Typically the houses had four or five floors over the cellars: ground floor, main floor, second, third and attics (roofs), depending on the width of the street they face. In figure 7 is shown a house built in Madrid in 1747.

. . . Que sobre las medias varas de las fachadas continuando su elevacion se hayan de sentar los pies derechos, y carreras de tercia para entramarla por el alto del cuarto principal disminuyendo las paredes por la parte ynterior hasta quedarse en pie y medio, y se devera fabricar eligiendo los vanos de ventanas de buena fabrica de Alvañilería . . .
. . . Que se haya de levantar el alto del quarto segundo con sus entramados en las fachadas de madera de tercias del mismo gruesso de pie y medio de buena fabrica de Alvañilería, y en lo ynterior de sesmas y taviques de yesso y cascote guardando los plomos de los vanos como muestra el alzado . . .
. . . Que en la elevación del quarto tercero se haya de continuar con los mismos entramados de tercia con carreras y puenttes de la misma calidad de pie y medio, del propio grueso en las fachadas, y de la misma fabrica de alvañilería dejando sus vanos de ventanas como expresa el alzado, y sentando las soleras ynteriores al nivel de las exteriores . . . AVS. 1–46–3 (1747).

In 1790, a great fire ocurred in the Plaza Mayor of Madrid, where more than 50 houses burned, and was only stopped at a house totally built with masonry. This

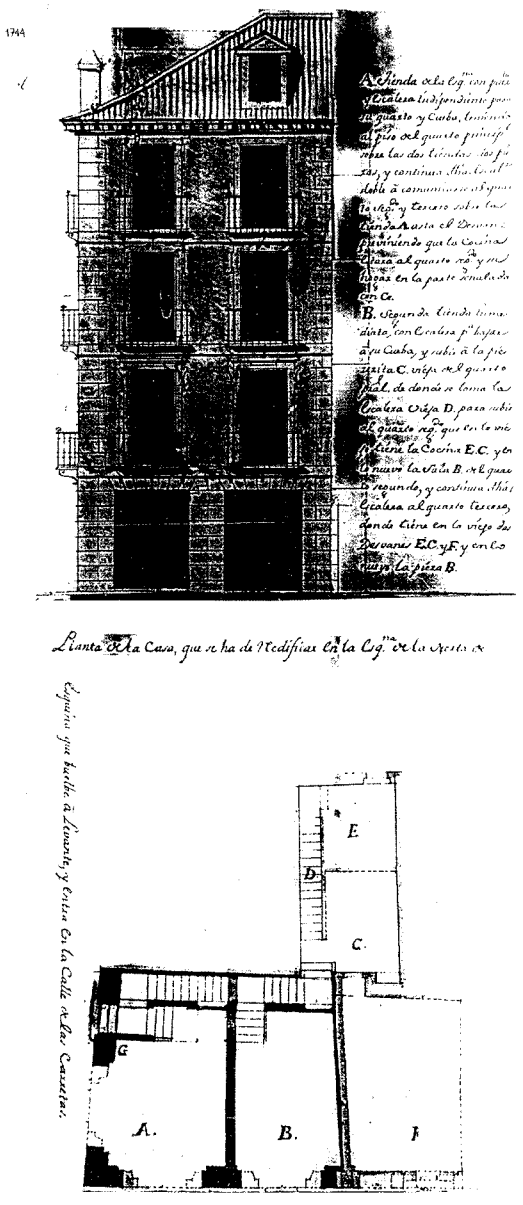

Figure 7
House built in the Puerta del Sol in 1747. AVS. 1–46–3

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occurrence, as well as the fire-prone constructive systems usually employed in Madrid houses, caused Juan de Villanueva [3] to advise building façades totally of masonry in Madrid, and to not allow wooden elements. In the following century most of the houses were built from the foundation to the eaves of the roof in masonry, and leaving wood framed construction only for thin walls, party-walls, partitions and «corralas» walls.

- Timber-framed thin walls, «cítaras» or «tabicones». Villanueva in his book «Arte de albañilería» explains these two different building methods. He suggests to build these walls only with masonry, and not wood, but in practice wood structural walls continued to be built until the start of the 20th century. The section of the wood elements used in the «cítaras» also decreased as the house grew higher. That is, the ground floor used beams of tercia, the main floor used beams of sesma, the second floor beams of «maderos de a 6», the third floor beams of «maderos de a 8», and so on as in the contract of work shown in figure 8.

In the two next abstracts we refer to it.

que el salon alto se compone de una zítara a la parte de la calle y un tabique dentro. La citara nezessita mas cuerpo y esta se a de acompañar y crezer echando solera abaxo y carrera arriva de quarta y sesma labrada y nudillos que abrazen solera y lo que se anide y pies derechos y puentes en las bentanas y riostras dando de gruesso a esta pared todo el largo de la calle de dos pie y medio porque defienda en berano del mediodía y lo mismo a de ser la pared que cay al oriente por su defenssa ase de maçiçar el pie y medio de dicha citara de yeso y cascote echando gatos que una uno con otro baxando lo que le toca a dicha citara . . . AHP N1 10.849 (1669).

Tabiques principales, sobre que han de cargar los suelos, y el de la escalera, que cae al Patio, han de ser sus carreras de madera de terzia con sus respectibos entramados, hasta recivir el suelo de los desbanes, y de alli arriba seran de vigueta, y sesma, sacando sus cepas sobre el firme de mamposteria, y sobre ellas sus buenas vasas de piedra verroqueña; y los intermedios la misma mampostería de media bara de grueso hasta la superficie, y desde alli hasta enrrasar con dichas vasas, sera su citara de ladrillo de un pie de grueso. AHP N1 16.455 (1760).

In the contracts of works, they also include the construction of staircases timber walls.

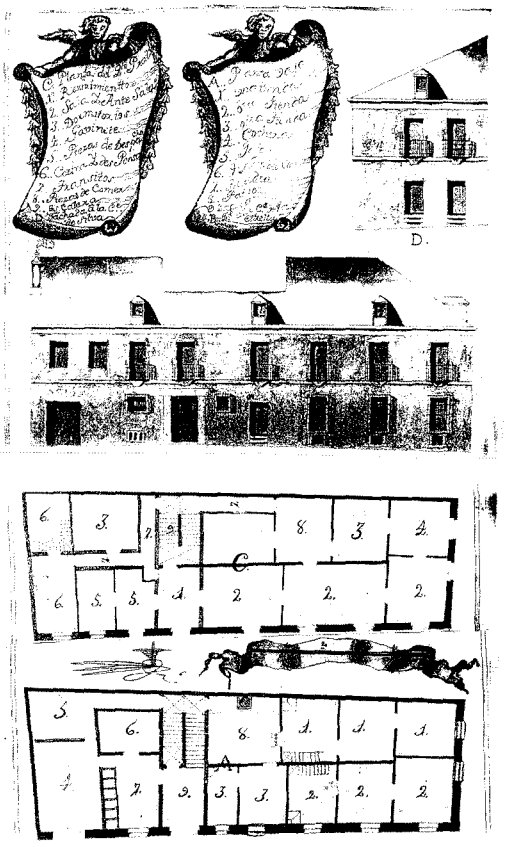

Figure 8
House built with timber-framed walls: main walls, thin walls, timber partywalls and timber partitions. AHP N1 10.849 (1669)

y en lo ynterior se deveran entramar los taviques para formar las escaleras, vajo de sesma, y el de la zitara que hunde vajo de tercia, y los peldaños de las escaleras han de ser de viga de pie y quarto desde el primer sotano hasta el ultimo del desvan con sus entradas suficientes en las paredes y taviques para su seguridad. Y por que al pisso del quarto principal empieza la escalera que tiene su entrada por la Calle de las Carretas de otra forma que atajo y se reduze a yda y buelta, y carga sobre el suelo un tavique que para recivirle se pondra una tercia donde cargue la division, y continuará esta por toda la altura como expressa el alzado . . . AVS 1-46-3 (1747)

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- Timber-framed party-walls or «telares de medianería». These walls were built with «telares» that is a main wood vertical structure surrounded with ropes or «tomiza» and separated by 5–6 feet. Then a wooden capital was placed on the columns and over it the beam used to support the floors. The spaces or «cuarteles» left between wooden vertical and horizontal elements were filled with different materials: «mampostería», adobe, brick, rubble or «cascote», etc. as it can be seen in the figure 9. The section of the wood elements also decreased as the house grew higher, similar to the construction of façades. The name usually given to each wood structural framework, depended on the width of the wooden element «carrera» and from it builders dimensioned the rest of the wood structure.

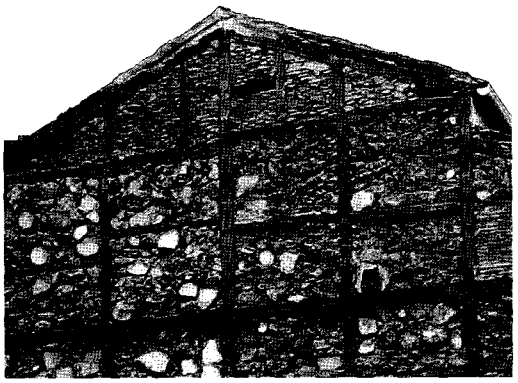

Figure 9
Timber-framed partywall or «telar de medianería». C/ Ventura de la Vega

las medianerías con sus vasas y carrera de vigueta, â sesma entramadas de sus respectibas maderas . . . AHP N1 16.455 (1760).

- Timber-framed partitions. When building framed wood partitions, builders often tried to support them from perpendicular walls so as not to add too much weight on the floors. Lightweight fill materials such as adobe, brick, and small rubble, but most often with plaster. Their dimensions varied between 1, 3/4, 1/2, and 1/4 foot. They were usually built in two ways: 1) supported directly on the floors employing mainly «maderos de a 6», «maderos de a 8» or de» maderos de a 10' and with a filling of bricks, plaster or rubble or 2) with a hung construction supported on a beam spanning between perpendicular walls and using «maderos de a 8» and «de a 10» and filling them only with bricks or plaster. A third type was rarely used built with adobe (rubble and plaster).

Los tabiques de quarto principal (de las divisiones) algunos de ellos, como son los que cargan en los vanos, se haran colgados, que estos bien echos, quanto mas delgados, son mejores, pero a donde no vea nezesario esta prevencion, se haran de medio pie de grueso, y lo mismo en los desbanes; para demas tabiques de divisiones de lo bajo, de forja de madera de a diez su entramado con sus vasas ordinarias, cepaes y citaras . . . AHP N1 16.455 (1760).

- «Corralas» walls. The final type of walls that will be studied in this paper are the «corralas» walls, made of open wooden framing which supported the galleries around the interior courtyard. In «corralas» houses, a series of corridors are supported by an open framework of vertical and horizontal timber elements. These types of walls were also called «courts entramados». These structural walls in corridor houses had around 3/4–1 foot (21–28cm) width.

Wooden floors

Historically floors were built in wood until the end of 19th century, when they began being built with steel beams. From a structural point of view, the constructive system employed was a horizontal structural frame of timber beams supported in main two-layered or timber-framed façade walls covering main spans of floors. Structural floors organisation varied depending on the spans; in buildings of only one bay (span), for very small distances (3.0–4.0) meters, the beams were directly supported on the masonry or timber-framed walls; when the spans were of medium length, that is, (5.0–7.0) meters, the beams were placed perpendicular to main walls and

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small beams following the direction of main walls; in those houses with large spans, that is, (8.0–9.0) meters, it was recommended to build the house with two bays (spans) following the timber beams the longitudinal direction. The perimetral supports were solved whether in the lateral party-walls or in the façade and back court walls. The central supports were solved with pillars or with secondary walls or «cítaras». Even if the spans were in every floor the same, the section of the timber framed floors could vary depending on the height of the house: main floor, second floor, third floor, etc.

They were basically built in two different ways according to the separation of beams: 1) «hueco por macizo»; and 2) «hueco wider than macizo». The spaces left between them were filled with rough masonry work or different timber planks nailed together. Next we will explain each of them.

Timber floors constructive system solution «Hueco por macizo»: This solution consisted of separating the beams by around the same width as the width of the beam itself. This distance could vary (5.0–11.5) fingers. The most common timber sections used in this floor solution were the «maderos de a 6», «maderos de a 8» and «maderos de a 10». The spaces left between them were solved whether: 1) with timber planks or «enlistonados», 2) with bricks which were placed directly on the beams and the under part was left uncovered or with a false roof; and 3) filled with rough masonry work. In figure 10 we can see a photograph of it.

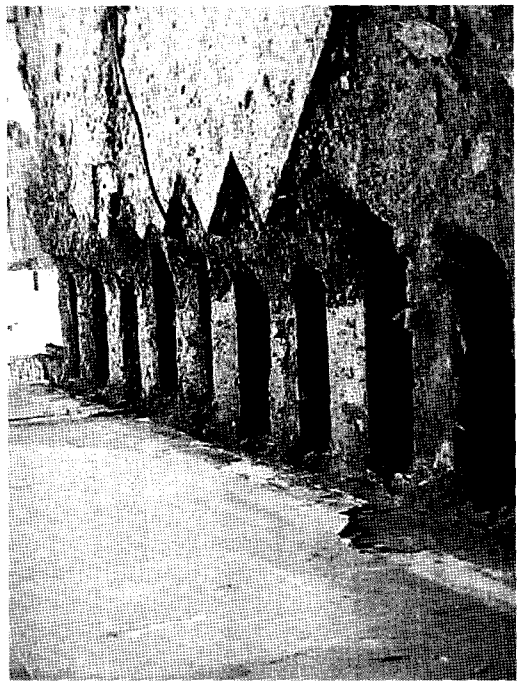

Figure 10
Timber floors constructive system solution «Hueco por macizo». C/ Relatores

> hechando los suelos del quarto segundo en la pieza del angulo de madera de a ocho cargando las cavezas en la fachada de levante y en la pieza inmediata viguetas de a veinte y dos pies que carguen en la fachada del Norte . . .
> . . . hechando los suelos del quarto tercero en la pieza del angulo de la misma madera de à ocho y al contrario del antecedente del quarto segundo cargando las cavezas en la fachada del Norte, y en la ynmediata de viguetas en la misma conformidad . . .
> . . . hechando sus suelos de desvanes en la conformidad que los del quarto segundo . . . AVS 1–46–3. (1747).

Timber floor constructive system «Hueco-macizo». This solution consisted of separating the beams a distance wider than the section of the beam itself and around (1.5–3.0) feet width. The most common timber sections used in this floor solution are third and fouth beam, fourth and sixth beam, «vigueta», «madero de a 6» and «madero de a 8». As in the preceeding section, the spaces left between them were solved in two different ways: 1) with planks and 2) filling the spaces left with rough masonry or «cuajado».

The introduction of steel beams for floors in the domestic architecture in Madrid did not appear until the end of 19th century. At that time the timber floors were substituted by floors with double T beams separated by approximately one meter and with the spaces left between them filled with ceramic «botes» and black plaster. This structure was supported on the main walls by steel squares and clamps. In a previous paper (González and Aroca, 2000) we have shown the comparative advantage prices for the steel and the underlying logic of the substitution.

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Roofs

The construction of roofs typically employed in historical domestic architecture in Madrid in 17th–19th centuries by studing the stages and their components: 1) roof wooden frames, main structure or «armadura» and roof wooden secondary structure or «pares», 2) «entablados» or floorboards made of «rastreles» and planks in a similar way as they built floors and, 3) covering elements.

Roof wooden frames (main structure and secondary structure). Roofs were built with a main wooden structural frame of beams and a secondary structural level of «pares» or small beams placed and nailed perpendicular to the first ones. They were built in different ways: a) «a la molinera», this was the usual type for roofs built to courts or «corralas». The «pares» or small beams are perpendicularly supported on main walls and over them they placed planks before placing the roof tiles going always only towards one direction; b) «par e hilera», in houses of two bays (spans) where over a central wall they placed very short pieces of wood named «enanos» and over them a «hilera» which served to build the ridge from where started the «pares» or small beams going to meet the beams placed on the façades and backwalls. They were then covered with planks placed paralell to the supports,

> que sentara cada pie de estribo i ylera de vigueta de quarta y sesma uno con otro por precio de dos reales y medio sentando los estribos a cola como es costumbre. Que sentara cada pie de vigeta de quarta y sesma en armadura por precio de sesenta maravedíes. Y si fueren vigetas que pasen de veinte y tres pies cada pie en armadura por precio de dos reales y un quartillo. Que sentara cada madero de a diez doblado en armadura por diez y seis reales. Que sentara cada madero de a ocho en armadura por veinte y dos reales. Que sentara cada pie de estribo de madera de a ocho sentado en caxas por precio de dos reales.. AHP N1 10.849. C/ San Miguel. (1669).

The third method, c) «par y picadero», is nearly the same type as the first one but, in this case, the «pares» are placed over the beams named «soleras» and «carreras», with cuts in the central piece named «picadero».

> . . . Que sobre otro suelo se haian de sentar sus aleros de sesma vien clavados contra los maderos del suelo que sirven de tirantes y sobre otros extremos en el angulo se ha de sentar por lima una tercia con un picadero donde se han de assegurar las pendolas y pares que seran de sesmas bien clavadas, y en ella y en sus cavios dejando las buardillas con sus antepechos de forma que demuestra el alzado y deveran ser de buena madera y conformacion todo entablado de chilla, y bien clavado y tejado convasisco à lomo cerrado con voquillas de yesso respaldadas y Cavalletes . . . AVS. 1–46–3. (1747).

2) Floorboards or «entablados»: «rastreles» and planks. Once this frame or main structure was raised, they placed small longitudinal pieces of wood or «rastreles» and planks nailed on them (often mentioned to be of «ripia»: 4 feet × 8/3 fg × 4 lines). Nonetheless Villanueva suggests to place bricks on them or «bovedillas» between them adding mortar in the under part to avoid the frequent and undesired fires that threatened Madrid. In the mid-19th century it was mentioned, as a posibility in the new by-laws of Madrid (1862), to build them with iron but, in fact, iron was not used until the next century.

3) Covering elements: roof tiles. After placing the planks, the most common and almost the only element used to cover the main wooden roof structure were the roof tiles. Nevertheless, for those new houses that could be built in the new «Ensanche» of Madrid, the contemporary by-laws mentioned a great set of other possibilities, such as metal plates of steel, lead or zinc.

Conclusions

This approach verified the uniformity of the structural construction systems of masonry: brick work and wood framed mixed with rough masonry used to build the domestic architecture in Madrid during more than three centuries. Once the main characteristics of the basic contruction elements are known, including the materials, dimensions and methods of construction, a structural analysis can be carried out to guide future interventions (if neccesary).

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AHP (*Archivos Histórico de Protocolos*) Documents mentioned: Nº 2.692, Nº. 16.366, Nº 10.849, Nº 16.455, Nº 7.055, Nº 16.968.