

# Proposal of a Methodology for the Architectural Design of Timber Houses

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## ABSTRACT

*This paper presents the principles of a method for the architectural design of timber houses based on the experience gained by timber companies. This proposal has as its major goal the challenging of the scenario of countries like Portugal where a shift in the design and construction methods integrating wood as a material could result in a much more sustainable habitat. A set of interviews was carried out with Portuguese companies in the sector of timber houses. They were questioned about their customers, design methods, the architect's role and the choice of structural systems. Based on the interviews it was possible to characterize the market and identify the main procedures about design. The most relevant ones were the importance of the architectural type definition, the support of a catalog, the relationship between formal and structural types and the architect's lack of knowledge about timber. The collected information pointed to an architectural design method to be used by Portuguese architects who, until now have often played a secondary role when a timber house was designed partly because the timber companies dominate the whole process. Some of these companies offer catalogues of design solutions that support customer's choices. The architects generally reject this type of method because of its supposed uncreative and impersonal results. The method here presented through some basic principles aims at collecting some positive lessons from the catalogue method, defining a process based on the recognition of Formal types and Construction types. This is the framework of a tool intended to help the Portuguese architects to deal with the range of the options available (solutions, companies, structural systems) and a support to help in deciding which construction system to choose.*

## INTRODUCTION

The adoption by architects of an architectural design method based on the information provided by the experience of timber house companies could lead to an increase in the use of timber houses. The replacement of Portuguese current concrete houses would originate several environmental benefits. The sustainable use of wood in single-family houses has been the subject of studies which conclude that there are advantages in its use over conventional solutions such as reinforced concrete (Monahan & Powell, 2011; Monteiro & Freire, 2012) and even over competing systems, such as light steel framing (Bolin & Smith, 2011; Rabbit, White, & Gervais, 2012). It is argued that the replacement of wood construction materials could result in a reduction of carbon emissions (Sathre & O'Connor, 2010). Even recognizing that there is no consensus on the results of such studies (Coelho, 2012; Gervasio, 2013) there are other arguments to consider when dealing with timber construction: the construction time and the prefabrication level. The average construction time for the current single-family houses in 2012 was 25 months (INE, 2013) while the construction time for wooden houses in Portugal is less than 6 months (Morgado & Pedro, 2011).

Although Portugal has a forest richness that could, with a growth in domestic demand, provide some of the raw material for construction (Marques Morgado, 2012; Machado, 2004), the old tradition of building some house elements such as roofs, floors and some walls with wood was lost. But in the final of the 20th century the scenario began to change with the appearance of pioneer timber house construction companies. Usually the whole design process was managed by these companies almost without the advice of architects. Besides, until recently structural wood was not considered by Portuguese architects as a solution. Today their growing interest by timber houses can be observed through three situations: 1) the presence of timber construction companies that integrate architects or are managed by them; 2) the emergence of a small number of architects who become specialized in timber construction; and 3) the proliferation of commercial or academic proposals for modular house designs in timber, with high impact on the architectural community, but with reduced reception from the real housing market. Moreover, the single-family house is one of the most important works of Portuguese architects (Domp, 2014). This way the architects, required by law to design a house (Law n. ° 31/2009), are very well positioned to inform their clients about the possibility of building with wood. Additionally, houses in Portugal are one of the most significant types of the building housing stock: 13.500 houses were built in 2012 against 1.212 apartment buildings (INE, 2013). However the architects' current design method may not be appropriate to timber house design. So this work does not focus on specific house solutions to reduce energy or to improve carbon sequestration. Instead of this it proposes a general method to allow architects to put into practice a more sustainable type of construction using wood, replacing the common practice of choosing by default concrete and brick.

### **Objectives and methodology**

The objectives of this article are:

- 1) To provide a summary of the results of 15 interviews with Portuguese timber house companies;
- 2) To propose the principles of a design method based on some aspects of companies' experience;
- 3) To identify the relevant typological principles connected with timber construction in Portugal;
- 4) To identify the main issues to integrate in design procedures;
- 5) To identify the relevant criteria for choosing a timber structure from the set of various solutions.

The current work involved:

- 1) The review of related literature and continuity with the research already carried out by the authors (Morgado, Guedes, Ferreira, Cruz, 2013; Morgado, Guedes, Ferreira, Cruz, 2012);
- 2) Interviews with managers, technicians or sales technicians;
- 3) Analysis of the interviews;
- 4) The proposal of a method to support architectural design through its basic principles.

Initially 25 companies were pre-selected and contacted, because they were among better well-known companies in the Portuguese market or represented the diversity of the national reality. Because of this, companies that do not refer the product "House" in their advertisements, or those whose structure seemed to be very fragile or only with a very short period of activity have not been considered. From the group of selected companies, 15 were interviewed with predefined questions and 10 showed no availability to answer. The interviews took place between April 10 and May 8, 2014, having been made in most cases in the headquarters of each company. Only in one case the interview was conducted using a form filled online.

The interviewed persons were: ten managers, two design technicians and three sales technicians. The headquarters of these companies are located in a vast territory extending 380 kilometres of the Portuguese coastline (up to about 60 km east inland) from Vila Nova de Cerveira (north) to Setubal (south). Timber houses account for over 80% of the workload of seven of the interviewed companies, while in the other eight there is a variation between 5% and 55% of their area of activity.

The interviews were supported by a questionnaire with eight main groups of questions: 1) Companies information; 2) Clients; 3) Construction Process; 4) Conception and design; 5) Role of the architect; 6) Choice of structural systems; 7) Structural systems' features; 8) Design method. The interview will be analysed as a whole in another publication, so only the relevant questions for the goals of this paper will be considered.

## **THE INTERVIEWS**

In the context of design methodology, national companies were classified based on the following criteria: the level of integration of the architect's activity, the number of building systems offered and the main companies' activity. Thus seven companies regularly work with architects, four occasionally work with them and the other four cover a market in which the activity of the architect is residual. Regarding the number of structural systems available for clients to choose from, seven companies offer three or more systems, four companies have only two systems and the other four companies emerge with just one structural system. All companies include design and construction activities (inside the company or with external partners) and five of them do not manufacture their products, as they are just partners of foreign factories.

### **Construction systems**

The dominant building systems are light timber-frame panels and post-and-beam, offered by eight companies and also the log construction present in six companies. With only three answers each system, appear cross laminated timber (CLT), light timber frame, plank and columns, three-dimensional modules and heavy mixed systems are present in three companies. Four companies offer heavy mixed systems (post-and-beam with light timber frame, planks or logs). The preferred system of most companies is the light timber-frame panels with four choices, followed by post-and-beam with three choices and cross laminated timber, light timber frame and heavy mixed systems with two choices.

### **Clients**

From the point of view of the interviewed companies, the arguments that lead a customer to choose a timber house are the Comfort (ten answers "very important" and four "important"), followed by the special architectural Aesthetics associated with wood (seven "very important" and six "important") and the Speed of construction process (five "very important" and ten "important"). The Environmental factors (three "very important" and five "important") and economics (three "very important" four "important") are less consensual. Regarding the type of agents who contact those companies, the final consumers are the most frequent, followed by architects. Most companies say that customers who approach them had already decided to build in wood. However the contacts are usually made in order to get a quote to compare with quotes those clients already have from other companies.

### **Construction process**

The most common construction process consists in the prefabrication of components regarding the specific settings of each project (twelve answers "often" and one "occasionally") and it is also common to use prefabricated market standard elements (five answers "often" and nine "occasionally"). However, the onsite manufacture with reduced prefabrication is still considered cost-effective by some companies (four answers "often" and three "occasionally"). Some companies work with complete modules (three answers "often" and three "occasionally") or partial modules. All companies considered that distance is not a limiting factor of the project's viability, although it may increase the final work cost. The final prices quoted by companies for a wooden house ranges from about € 500/m<sup>2</sup> up to € 1000/m<sup>2</sup>. The average price indicated by the 15 companies is about € 800/m<sup>2</sup>.

### **Method and design conception**

Most companies (with one exception) consider, among other possibilities, the timber house design as a completely custom solution. All companies include a showcase of solutions available for client consultation, functioning in some cases as "catalogues of solutions" or books of patterns. This is a common device in the companies activity, whether based on pre-defined solutions (eleven responses), or based on a customisable modular system (six responses). The companies with a larger production of houses tend to offer a detailed catalogue presenting different types of solutions grouped in families of "styles" and structural types. Only two companies declared not to provide such a device, coinciding with situations where timber houses are a secondary activity. Among companies using the catalogue of solutions, only two considered it to be "less important", with the others considering that it is "very important" (five responses) or "important" (six responses).

The purpose of the "catalogue of solutions" is for most companies (seven responses) a reference to support customer choices, with only two companies considering that the catalogue offer products that customers actually accept and buy without any changes. Four companies considered that catalogues work more as a marketing medium. It was noticeable that several companies use their already built houses or their exhibition prototypes as models that act also as a "catalogue". When addressing the companies, most customers already have a pre-set idea of the functional type of house they want to build (twelve responses), but are often less informed about the symbolic type (language, proportions, details, finishes) and it is frequent that they are not enough aware about structural type definitions. Although with less answers, the client without predefined ideas also consults the companies for the support of the design services from early stages (two answers "often", nine "occasionally"). Architects, as expected, consult those companies with more defined ideas about functional and symbolic solutions, although not often with pre-defined ideas of the structural types. Companies use the pre-defined customer ideas as a starting point, although some minor adjustments (fourteen responses) are always required. When customers do not have pre-set ideas the most widely used process is the customization of solutions based on the catalogue (eight responses) and the definition of completely customized solutions process.

### **The architect's role**

All companies offer architectural design, structural engineering and the other engineering services. However seven of them hire external architecture services and other seven hire external structural engineering services. The intervention of architects, in addition to the design development phase for authorities' approval, is generally lower in the phase of construction documents and in the coordination tasks. It should be noted that normally, in cases where the architectural services are hired by the client, the company prepares a set of documents to be reviewed by the architect responsible for the design approval. Regarding the knowledge of timber construction specificities, the architect is seen by companies as a professional who demonstrates "many difficulties" (seven responses) or "some difficulties" (seven responses). The most highlighted aspects were the difficulties about durability constraints (eight responses "many difficulties" and five "some difficulties"). The structural and hygrometric behaviour of wood and the construction details were also highlighted, although not with so much importance. It may be added that one of the interviewees considered that cases where the architect's solutions fail are explained by the importing of architectural models from central and northern Europe, whose performance in the national climate (thermal and humidity conditions), turn out to be deficient. The architect is nevertheless considered an important partner, as expected, for the completion of approval designs, the implementation of the program and the definition of formal solutions. Questioned about whether the intervention of the architect leads to more complex, more expensive, or later problems, most companies found that it does not affect the normality of the work, although some companies indicated negative responses and no company indicated that the architect's intervention has a positive effect on these parameters. Five companies answered that architects are responsible for more complex processes, four mentioned higher costs and three mentioned later problems. Most companies defend that the structural engineering must be integrated in the company (eight responses), opposite to a minority (four responses) that consider that it should be integrated into the project team or that should be hired by the company (two answers). Some companies noted that when the structural designs are undertaken by external offices, the structural components tend to be the oversized.

### **Choosing the structural systems**

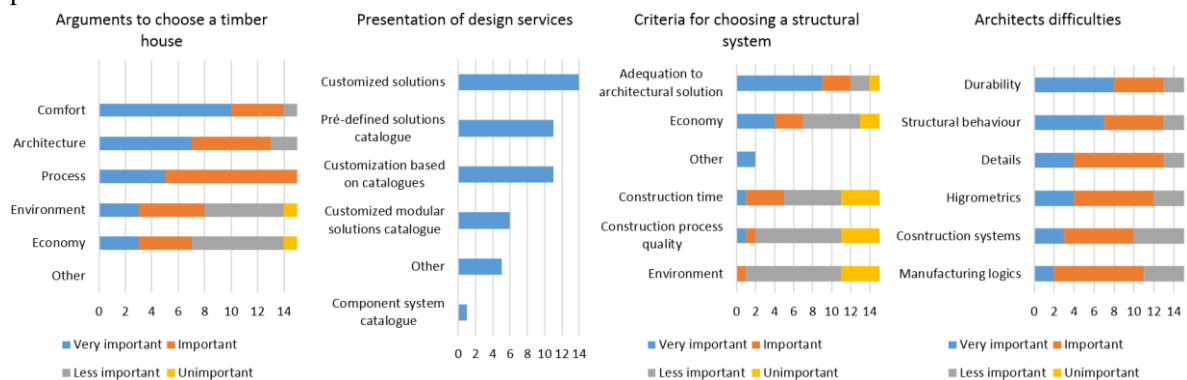
During the initial project definition, clients do not usually think about structural systems. Half the companies responded that it is rarely mentioned, while three considered that this aspect is never mentioned. The choice of structural types occurs frequently (seven responses) and occasionally (eight responses) simultaneously to the choice of the formal type. It is also frequent (nine responses) and occasional (three responses) that the choice is made after the formal type definition. Only in three cases was the choice of structural type done beforehand (frequently and occasionally). The simultaneous choice of structural and formal types occurs mainly in cases in which companies have an organized catalogue of solutions associating a structural type to each formal type. Some interviewees mentioned that when clients choose as a reference the catalogue solution, they already know which structural system will fit better.

The choice of the structural type which is usually held in the early stages of the project is done by considering the adequacy to the architectural solution as the most important criterion (nine responses "very important" and three "important"). The remaining criteria are less important, but economy is still the second most mentioned criterion, being considered as "very important" (four responses) or "important" (three). The other mentioned criteria are the construction schedule, the quality of the construction process and finally, the environment is considered a "less important" criterion (ten responses) or "not important" (four responses). Regarding codes and standards, the majority of responses devaluates its impact on the choice of the structural system, with most companies responding that their influence is less important or unimportant. However, the thermal requirements are those to which companies assign more importance over the other ones (structure, aesthetics, specific timber standards), with one "very important" response and four "important" responses. For the characteristics of the built envelope, seven companies said that different climatic zones have influence in their settings while eight said exactly the opposite. These latter companies said that the offered solutions always include the definitions to face in the most unfavourable situation.

The influence of structural types on the settings of formal types was considered mainly as "less important" (nine responses) or "unimportant" (two answers). The comparative analysis of structural systems is undertaken "often" or "occasionally" by seven companies, and "rarely" or "never" by the remaining eight. When questions were asked about the adequacy of structural systems to specific architectural characteristics, the responses were predictable, associating the post-and-beam to wide structural spans and larger windows, interior open spaces, stylistic flexibility, contemporary and "structural truth" character. The light timber frame panels were associated to stylistic flexibility, contemporary character and with minimized loads on the foundations. The log construction and the column-and-planks were associated to the "structural truth" character and the traditional character (though one company does believe that the contemporary character is also possible). The cross laminated timber panels are also mentioned, but less often (because only three companies work with them), associated to large spans, protruding volumes, stylistic flexibility and contemporary character.

## Design process

Most companies (fourteen responses) can easily provide a construction cost estimate with a sketch drawing (1/200 scale), implying the existence of reference prices per square meter, although there are additional factors to consider such as the level of quality of finishes and the scale factor, reducing the price by square meter as the amount of work increases. With a design development project (1/100 scale), all companies already provide a final budget. Companies are flexible about the time the contract administration should take place, most of them (nine responses) considering that this step must only occur after the municipal approval is obtained. Throughout the interviews development, it was noted that the issue of construction documents (construction drawings) phase executed by the architect only occurs in some cases, as a large part of the details and specifications are made by the company. The detail drawings of architecture tend to be complementary (when they do exist) to manufacture and assembly drawings of the structure, envelope and interior partitioning. Seven companies think that the construction drawings must be coordinated by the company, while four answered that it should be a simultaneous process.



**Figure 1** Some interview results based on 15 answers: (a) Arguments to choose a timber house (b) Presentation of design services (c) Criteria to choose a structural system (d) Architects difficulties.

## **ARCHITECTURAL DESIGN METHOD**

An overview of the design process adopted by companies of timber houses and architects in Portugal can be described through the following three reference models (A, B, C):

A - Developed by the timber house sector companies. With solutions built from tested designs or catalogues or still modular systems (although contemplating customization). The companies have a preferred range of structural systems to offer. The architectural services in each project can be minimized due to the accumulated experience and the repetition of solutions. The advantages of this process are construction quality and process efficiency. Architecture in this case is understood as a product. The client chooses the product, but he must adapt himself to the company's standards and offer.

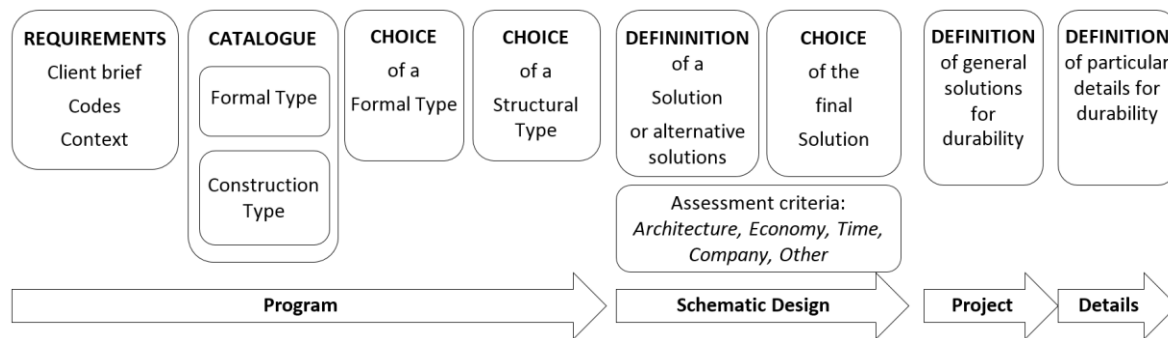
B - Developed by architects according to the model propagated by architecture schools in Portugal. With solutions based on the specific nature of each commission and ruled by conceptual principles or inspiring models of contemporary architecture, with the aim of obtaining unique and innovative features, with a large investment in aesthetics, more than durability. The architect integrates the well-known construction system with reinforced concrete. The architectural services are carried out with great endeavour in construction drawings. The advantages of this process are its formal quality and uniqueness. The resulting architecture is seen as an artistic product. The client chooses the architect, but he should adapt himself to the architect's choices.

C - Developed by architects who provide services adapted to the reality of the average client of the single family houses in Portugal, with the aim of their satisfaction. With solutions based on preferred customer models and with reduced conceptual and aesthetic thought. The building system makes use of the current reinforced concrete. The architectural services are performed with reduced effort in construction drawings, using known details. The advantages of this process are the smaller costs of the design services, and the improved customer satisfaction, but the resulting architecture is often a rather banal product. The customer chooses the architect and this one must then satisfy his particular requirements.

We want to propose now an alternative system: D - To be developed by architects under a collaborative process with the wooden houses sector companies. With solutions developed from a knowledge base made by a "catalogue" of architectural types which provides information on achievable solutions with timber structures, recognizing customer preferences but expanding the range of available solutions and the suitability to each scenario, with great emphasis in construction drawings and in durability concerns. The advantages of this method, compared to the process A, are the greater range of customer choices and the independent support that is provided. Regarding process B, communication and customer satisfaction are improved by a choice supported by a typological catalogue, seeking to obtain durable solutions. Finally, in relation to procedure C, there is the advantage of offering a personalized service with greater effort in architectural thought and greater conceptual attention to context and a more sustainable solution in wood.

### **Typological systematization**

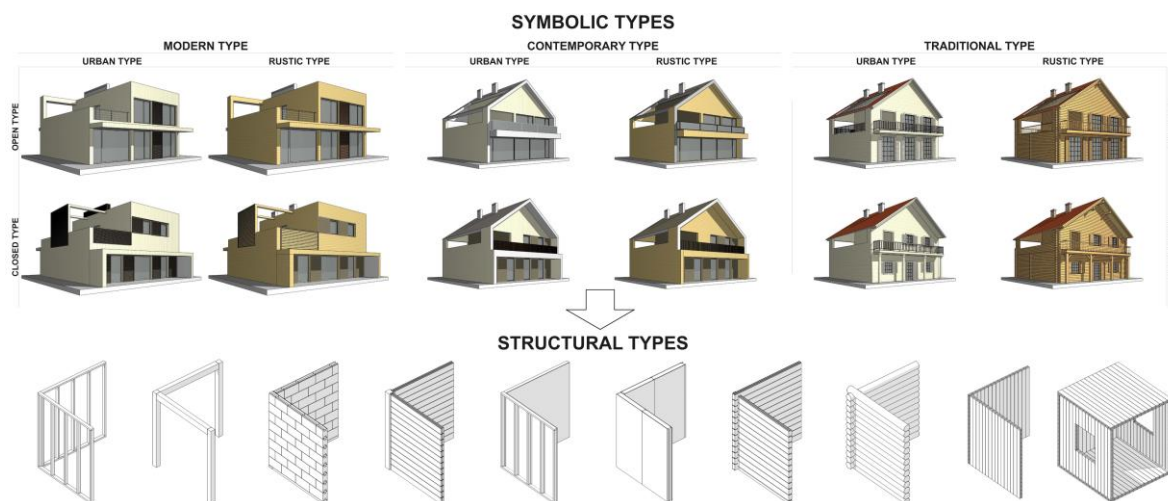
The typological systematization of the timber houses universe will be part of the information that allows us to acquire knowledge of market possibilities and that enable the communication between architect and client. The set of possible types results from the subdivision of architectural types into subtype systems. Thus, each architectural type includes a formal type and a construction type. The first is defined by features of architectural design, while the second is defined mainly by engineering features. The formal type can in turn be subdivided into functional, spatial and symbolic types (Figure 3). The construction type can be subdivided into structural, envelope and partition types. Although the "types" can be described by rules, thus being different from "models" (or concrete solutions), it is useful to build a "catalogue" with models which represent the main types, because it will improve the communication between the client and the architect, avoiding misunderstandings. Dialogue can be established enabling the client to make choices from the various possibilities. On the other hand, architects can advise the client about the most adequate type of solutions without missing possibilities. The symbolic type is particularly important in the context of architectural types. It is defined in terms of characteristics, such as the roof shape, the degree of openness and the kind of finishing. The structural type (Morgado, Guedes, Ferreira, & Cruz, 2012) is of great importance in the context of building types, defined according to the characteristics of its vertical elements.



**Figure 2** Proposed procedure based on architectural types.

### Proposed design method

After the collection of data gathered from the context (codes, standards and customer requirements which include the functional requests, values and preferences, cost limits, construction time limits and environmental sensibility) the program is defined by the architect. The program will be based on the definition of successive types: functional type, spatial type and symbolic type which together define the formal type. After that the construction type will be defined: structural type, envelope type and partition type, but at any time the decisions can be questioned, thus implying a comeback to any previous stage. In the sketch design phase, solutions are developed and evaluated based on the selection criteria and respective weights defined in the previous phase. The structural solution (or structural solutions, in case there exist alternatives) will be evaluated based on the suitability to the architectural solution, the economy (including the costs provided by companies), the process (including deadlines and assessment of companies) and possibly on environmental impacts of the solution and also other criteria defined for each case. After the solution and the construction company have been chosen, the activity of the architect, besides the integration of all engineering services, will be focused on the architectural features that can ensure the durability of the building through the general settings and particular details.



**Figure 3** Example of a typological catalogue made by symbolic types and structural types

Following this proposal it is required that the architect welcomes a set of new practices and new skills: 1) It is required a knowledge of the cultural aspects of wood architecture to support the choice of formal types; 2) It is required a knowledge of structural systems and the understanding of its relation with architectural forms; 3) It is required an awareness of the criteria for selecting the structural types; 4) This calls for a better understanding of the specificities of wood and the constraints of durability. Architectural firms interested in building wooden houses could also define their own catalogues, following the suggestion of Colin Davies (Davies, 2005): "Pattern books could be used to promote the sale of certain commercial products, but more importantly, they could also be used to promote good architecture and sound, sustainable building practices (...) It seems completely feasible for architects to adopt, or readopt, the pattern book principle. It may even be an essential precondition for the achievement of that century old ambition to bring architecture to the masses".

## CONCLUSION AND DEVELOPMENT

Based on interviews conducted with the timber houses design, manufacture and construction companies, it was possible to recognize some important aspects of the national market and of the design process. Based on the information collected, the framework for a proposed method targeting the optimization of timber house design in Portugal was outlined. The information that had greatest impact on the proposal were: the existence and the importance of a typological catalogue, the relevant criteria for the choice of structural type (suitability for the architectural solution, cost limits and construction time), and the difficulties evidenced by architects in relation to wood construction. This last situation requires some actions to improve the knowledge about wood considering the solutions' durability. The details of this proposal are in development within a Doctoral Thesis, with several Portuguese companies supporting case studies aimed at testing the characteristics and constraints of each construction system.

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