

# MATERIAL KNOWLEDGE FOR DESIGN – THE ARCHITECT’S VOCABULARY

Lisa Wastiels<sup>1</sup>, Ine Wouters<sup>1</sup> and Jonas Lindekens<sup>1</sup>

<sup>1</sup> Department of Architectural Engineering, Faculty of Engineering Sciences, Vrije Universiteit Brussel, Brussels, Belgium, Lisa.Wastiels@vub.ac.be

## ABSTRACT:

This paper investigates how architects select materials during the design process. It argues that not only performance aspects are factored in, but also aspects related to the experience or sensorial stimulation take part in this choice. The argument starts by constructing a hierarchy in the vocabulary that is used to discuss spaces, elements and materials. This hierarchy is derived from the data collected during five in-depth interviews with architects, discussing their own projects, and provides a framework to discuss the different concepts considered during the design process. Consecutively, one of the interviews is studied in more detail – in reference to the developed framework – in order to find out how the attributes of space and elements help defining the attributes of the materials, and vice versa. The paper is concluded by indicating how further research will help consolidating the early findings of this study.

**Keywords: Material selection, Experience, Architecture**

# 1. INTRODUCTION

## 1. 1. MATERIALS IN ARCHITECTURE

“Good architecture is not just about primary functions. You must also take into account secondary and tertiary functions, and even beyond that. A space is never about one thing. It is a place for many senses: sight, sound, touch, and the unaccountable things that happen in between.” – Tadao Ando (in Auping et al 2002)

Most of the time, materials serve more than one purpose. Choosing materials for an architecture project is not only about meeting technical requirements, the material's appearance and sensory behavior play an equally important role while designing (Ashby and Johnson 2002) (Fernandez 2006) (Pallasmaa 1996) (Malnar and Vodvarka 2004). While selecting a material, the architect looks into performance aspects – such as the material's durability or compression strength – but also considers aspects that concern the user experience or sensorial stimulation – like the color or visual texture. Moreover the architect might have a certain atmosphere in mind that will be reflected through the materials – like a ‘formal’ feeling for a lawyer's lobby, or a ‘trendy’ feeling for a lounge bar. The avalanche of new materials made available to architects and designers everyday, necessitates rethinking the traditional classification or characterization of materials (Addington and Schodek 2005).

## 1.2. MATERIAL INFORMATION

Lists of properties of different materials are described in numerous handbooks and on various websites. However, most of these sources focus exclusively on the technical performance of materials and give little consideration to the aesthetics or experiential aspects described above. The conventional material selection tools in engineering and architecture do not address aspects relating to the perception and sensorial experience of materials. In addition, most selection tools require a high level of familiarity with the technical aspects of material science which prohibits easy and productive use of these design aids for architects.

Recently the interest in material sensitive applications and material specific design within the architecture context has increased. Material consulting companies, such as MaterialConneXion and Materia<sup>1</sup>, emerge across the globe and the number of books focusing

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<sup>1</sup> MaterialConneXion and Materia are both companies that provide material consulting services, as well as a physical material library for their clients (mainly architecture and industrial design). More information about their activities can be found at [www.materialconnexion.com](http://www.materialconnexion.com) respectively [www.materia.nl](http://www.materia.nl)

on the different aspects of materials in a design context keeps growing (Ashby and Johnson 2002) (Fernandez 2006) (Keuning et al 2004) (Beylerian 2005). However, this interest seems to be rather random at this point, and represents no clear relation between the materials themselves and the way architects think about or work with these materials. At no point is the thought process of the architect made tangible, nor are the intangible characteristics of the materials objectified.

Contrasting to the discipline of architecture, a substantial amount of research has been done on the experience of products (materials and form), and the different characteristics and phenomena that are at play, in the discipline of Industrial Design (Desmet and Hekkert 2007) (Schifferstein and Cleiren 2005). Several tools have been developed to assist the designer with decision making during the design process (Sonneveld 2007) (van Kesteren et al 2007). Karana and van Kesteren (2006) found that people not only concentrate on the physical characteristics of materials but also evaluate non-physical ones, such as sensorial characteristics or characteristics of perception. Several findings and definitions established within the Industrial Design discipline could be translated to Architecture, but only after careful consideration of the significant differences between the disciplines (such as the larger scale, the visual focus, and the user interaction).

In order to get a better idea of the architect's needs in terms of material information, this study examines some of the concepts architects work with while selecting materials. At the same time the study aims to develop a more comprehensive framework of material aspects that are considered during the design process.

## 2. METHOD

In-depth interviews were conducted to inquire what aspects of materials architects consider while designing a building (and while choosing its materials). The aspects of materials considered during the design process were identified in the interviews and served as raw data for further analysis and data grouping. A detailed description of the process is described below.

### 2. 1. IN-DEPTH INTERVIEWS

Ideally, architects could be observed and interviewed during the actual design process in order to reflect all the different considerations concerning materials along the process. As this process typically takes months or years to be completed, and the observation might affect the design process, the long interview (McCracken 1988) was chosen as a method to take the architects back to their thought process at the moment of the design. We are aware of the

drawbacks that this method entails (Lawson, 1990). This approach is exploratory though and gives the opportunity to glimpse the complicated character and logic of material choices within the design process without the troublesome burden of following a project during several months. The intention of this study is to provide a preliminary framework for discussing the characteristics of materials that are desirable (or even necessary) information for architects.

## 2. 2. INTERVIEW SETUP

As it is not our intention to generalize our findings, but rather to explore aspects concerning material choices in architecture, we do not need a statistical sample (Trost 1986). The subjects were chosen based on their professional experience (to ensure an autonomous completion of a design process from beginning to end) and the international character of their work (so that local uses and habits are filtered out). Five in-depth interviews – each on at least two design projects – were conducted with experienced architects (15 to 30 years of experience) ranging between the age of 39 and 60. All of them were based in Boston at the time of the interviews but most of them worked internationally (Europe, U.S., Asia) at the time of the interviews or before.

The interviews were conducted in the architect's professional environment and lasted between 1h20m and 2h15m. All interviews were tape recorded and transcribed. The subjects were asked beforehand (by email) to provide documentation on two built projects where they had been closely involved in the design process (from conceptual design phase to execution). The interviewees were told that we wanted to have a conversation about the general intentions and main concepts of the projects, as well as the different options that were considered during the design process. However, they were not informed on the exact topic or the focus of the research. As they did not know that the materials were the focus of this study, they were not biased when talking about the projects.

A protocol with open-ended questions about the general concepts and the choice of materials was used as a guideline for the interviews. Typically the interviews started with the question to talk about the project and its general concepts. Later on the prompts and questions focused more on the materials applied in the project. 'Why did you choose for this particular material X?', 'What issues did you consider when choosing this material?', 'How would the use of material Y have changed the project?', 'What alternative materials were considered along the process, and why?'...

### 3. DATA COLLECTION AND ANALYSIS

#### 3. 1. DATA COLLECTION: INTERVIEW VOCABULARY

The audio taped interviews were transcribed into a word processing program. The recorded time is marked by hours and minutes [hh:mm] at the start of each paragraph for easy referencing during the analysis. First the interviews were manually scanned for words that relate to materials, their behavior, or any direct or indirect architectural implications of the material considerations. Examples of such terms are *'dark'*, *'cold'*, *'acoustic'*, *'durable'*, *'fragile'*, etc. This list of adjectives, adverbs, nouns and verbs – being the *material vocabulary* – was identified for each of the interviews and served as a basis for the data grouping. More examples of the vocabulary can be found marked in italic in Column 3 of Table 1.

A further evaluation of the interviews revealed that sometimes the materials are not mentioned explicitly but that the material attributes are assigned to the architectural element, like the wall, the ceiling or the floor. Examples would be *'a hard floor'*, *'an opaque wall'* and *'a fragile element'* where each of the adjectives to describe the elements in a way also reveals something about the material.

Building on this logic that materials form elements and elements create spaces, the interviews were also scanned for description of spaces. Quotes such as *'the room is very sunny in its color'*, *'the Art buildings are extremely tough'*, and *'a formal but progressive place'* recur in all the interviews.

Because of the slim boundary between describing what a material contributes to the architecture and how the elements or the space influence the architecture, the interviews were analyzed in a similar manner for elements and spaces as described above (and below) for materials. This implies that for each interview three lists of used vocabulary have been constructed: one list for material references, one for element references and one for space references.

#### 3. 2. CONSTRUCTING A HIERARCHY: BUILDING HIGHER ORDER CONCEPTS

A three-step process was used to organize the data into a hierarchy: a) data grouping, b) secondary level labeling, and c) primary level labeling (Ulrich and Eppinger 2000). This process was repeated for the *Material* vocabulary, the *Element* vocabulary and the *Space*

vocabulary for each of the interviews. Table 1 provides a demonstration of the content analysis for one of the interviews, in this example for the *Material* vocabulary.

Table 1. Demonstration of the analysis process (for: Interview 1, focus Material vocabulary)

direction of hierarchy  $\longrightarrow$   $\longleftarrow$  direction of content analysis

Primary level labeling	Secondary level labeling	Data grouping
<i>DOMAIN</i>	<i>THEMES (codes)</i>	<i>(Material) VOCABULARY</i>
1 Physical behavior	<i>color</i>	"this wood is <i>dark</i> ", "zinc is a <i>darker, richer color</i> than aluminum", ...
	<i>texture</i>	"the <i>depth of the grain</i> of wood", "it has that <i>texture</i> , but it is metal", ...
	<i>temperature</i>	"concrete is a very <i>cold</i> material", "plaster feeld much <i>warmer</i> ", ...
	<i>mass/weight</i>	"concrete is a very <i>massive</i> material", "it is of a similar <i>consistency</i> ", ...
	<i>visual/light</i>	"terrazzo has some <i>translucency</i> ", " <i>clear</i> glass", ...
	<i>hardness</i>	"concrete is a very <i>hard</i> material", "the plaster is a little <i>softer</i> ", ...
	<i>technical</i>	"the <i>shrinkage</i> of the material", "the zinc <i>oxidizes</i> ", ...
	<i>acoustics</i>	"an <i>acoustic</i> material", ...
	<i>flexibility</i>	" <i>there is some give to it</i> ", ...
	<i>geometry</i>	"a <i>thin</i> piece of wood", ...
2 Experience	<i>economy</i>	"the material is extremely <i>expensive</i> ", ...
	<i>association</i>	"an <i>industrial</i> material", " <i>North European</i> blond wood", ...
	<i>personality</i>	"this wood is, although <i>formal</i> , it is a little <i>fragile</i> ", ...
3 Function/Use	<i>emotion</i>	"stainless steel would have been <i>off-putting</i> ", ...
	<i>function(al)</i>	"concrete is more <i>durable</i> ", ...
4 Context/Environment	<i>use</i>	"concrete has this <i>utilitarian connotation</i> ", ...
	<i>ecology</i>	-
	<i>time</i>	"the <i>durability</i> of the material"
	<i>culture</i>	-
5 Manufacturing process	<i>context</i>	"an <i>interior</i> plaster finish", "the terrazzo is <i>in-place</i> and <i>of the place</i> ", ...
	<i>process</i>	"the sort of <i>hand-formed</i> zinc", "wood is a <i>moldy</i> material", ...
	<i>finish</i>	"a <i>metallic surface</i> "
	<i>(element) type</i>	-
	<i>assembly</i>	-

### a. Data grouping

The vocabulary extracted from the interviews (see 3.1) was grouped according to their content: words describing equivalent behavior or similar (material) aspects were classified into the same group, as shown in Column 3 of Table 1. For example 'grain', 'graining', and 'texture' were grouped together because they describe the same or a similar aspect.

### b. Labeling themes

The groups of words identified in the previous step were coded with a general keyword that represents the aspect in a more comprehensive and general way. As an example, the words 'grain', 'pattern' and 'rough' were coded by the keyword '*Texture*' because they all relate to the surface characteristics of the materials and more specifically the surface texture. These keywords were called 'themes' and can be found in Column 2 of Table 1.

The themes were identified as the characteristics of materials considered during the design process and material selection process. A word used to name a theme could possibly also be found in the list of vocabulary at the previous level (Column 3 of Table 1).

### c. Labeling primary domains

Within this (non-limitative) list of themes some larger cluster groups – called ‘domains’ – could be identified according to the similarity of the themes, as shown in the first column of Table 1. The themes defining a specific domain could be seen as different aspects of the same phenomenon. For example, the themes ‘*Texture*’, ‘*Color*’, ‘*Geometry*’, ‘*Mass/weight*’, ‘*Acoustics*’ do all speak to the physical behavior of the material. These themes – and their sub-vocabulary – can thus be categorized under the primary domain ‘*Physical behavior*’.

It should be noted, however, that this is only a preliminary proposal for grouping the different aspects that are at play when considering and selecting materials during the architectural design process. The idea behind the interviews was to develop a first framework exploring all the different aspects at play. For the development of a larger and more definite structure of considered material aspect (or themes) that is representative of the wider architectural community, a larger quantitative study with a statistical test sample would be necessary.

## 4. FINDINGS (RESULTS AND ANALYSIS)

Based on the data from the interviews five primary domains could be identified to describe the aspects that are at play when selecting and applying materials: ‘*Physical behavior*’, ‘*Experience*’, ‘*Function/Use*’, ‘*Context/Environment*’ and ‘*Manufacturing process*’.

These domains distilled from the interviews are in accordance with the statement by Ashby and Johnson (2002) that designers need information on the following dimensions in order to make a proper material selection: engineering, aesthetics, personality, use and the environment. Also the integrated model presented by van Kesteren et al. (2007) shows a lot of similarities with the primary domains presented here. Their model represents materials as one of the six design considerations within the context of industrial design: materials, manufacturing process, shape, form, use, and product personality. A thorough analysis of the differences between the hierarchy constructed in this study and the different elements considered in the field of product design is however not the subject of this paper.

The different hierarchies constructed for the Material vocabulary, Element vocabulary and Space vocabulary were compared and evaluated at the level of the primary domains. An overview can be found in Table 2.

In general, the same type of descriptions appears for Elements, Spaces and Materials. In section 4.1 a closer comparison through excerpts and vocabulary from the interviews points to the similarities and nuances between these descriptions, as well as to the different

considerations made during the design and decision making process. Each of the five primary domains and the differences in description of Materials, Elements and Spaces are described below.

In section 4.2 the constant switching between material, element and space is exemplified by some interview extracts on a particular material in one of the interviews. These interview extracts are evaluated through the framework of primary domains and themes presented above.

Table 2. Primary domains for Materials, Elements and Spaces

	MATERIAL	ELEMENT	SPACE
1 Physical behavior {P}	X	X	X
2 Experience {E}	X	X	X
3 Function/Use {F}	X	X	X
4 Context/Environment {C}	X	---	X
5 Manufacturing process {M}	X	X	---
(6) Material as attribute {A}	---	X	---

#### 4. 1. PRIMARY DOMAINS FOR MATERIALS, ELEMENTS AND SPACES

The domains Physical behavior, Experience and Function/Use are populated by a descriptive vocabulary encompassing the three aspects considered in this study – Materials, Elements, and Spaces (Table 2). The Context/Environment domain is not considered by the subjects when describing Elements. In a similar way, the domain Manufacturing process is not used at the level of the Space. Finally an additional domain – named Material as Attribute – was identified for the description of Elements.

All domains are discussed into more detail here. A more elaborate discussion of the content of the primary domains Physical behavior {P} and Experience {E} follows at the end of this section as these domains contain the main body of characteristics and expressions related to materials.

##### **Function/Use**

Few words are categorized within the Function and Use {F} domain. For Materials these aspects often relate to the interaction between a user and the material. For instance, the aspects ‘*slip-resistance*’ and ‘*durable*’ relate to the way in which people will interact with the material. For Elements and Spaces the vocabulary relates to the actual function of the element, such as an ‘*outer*’ screen and a ‘*retaining*’ wall, or the actual function of the room or space, such as a ‘*public*’ room.

### **Context/Environment**

The domain Context/Environment {C} is related to the themes of 'Ecology' (e.g. '*green*' and '*natural*' materials), 'Time' ('*maintenance*' and '*durability*') and 'Context' ('*vernacular*', '*local*' or '*in-place*'). For the description of Elements no vocabulary related to the Context/Environment was found (Table 2). This seems a reasonable finding as the themes of 'Ecology', 'Time' and 'Context', often relate to either material specific aspects (e.g. a *green* or *durable* material) or a larger spatial context (e.g. *friendly* to the environment or a *local* building).

### **Manufacturing process**

Vocabulary related to the process, finish or assembly is organized within the domain Manufacturing process {M}. The manufacturing process is not discussed when speaking of Space, so the domain {M} is only used in the context of materials and elements (Table 2). This seems a rather pragmatic result as a space could not really be *manufactured* or *finished*. Examples of vocabulary that can be found within the themes 'Process' and 'Finish' are '*crafted*', '*glue-lam*' '*reinforced*' and '*stained*'. The themes 'Type' and 'Assembly' are additional themes that only occur in the description of elements and focus on aspects such as '*shingle*' or '*mitered joint*'.

### **Material as attribute**

Even though it is not really a domain in itself, it should be noted that elements are described by an additional theme, being the materials themselves. In that case the material is used as a descriptor or attribute to specify the element, for example a '*wood wall*', a '*steel column*', a '*brushed aluminum window*'... This semi-domain represented in Table 2 as 'Material as attribute' {A} is only used when describing Elements.

### **Physical behavior**

Any word that relates to the purely physical aspects of an environment, or to the materials that it is made of, are in this study brought together under the common name of 'Physical behavior'. The sub-domains or themes included within this group can be found in Table 1. Data shows that the physical descriptors are the most commonly used to describe Materials. The majority of the material keywords identified in the interviews fits within the group of 'physical behavior'.

Within the domain of physical descriptions, we find that geometrical descriptors are far more frequently used for Elements and Spaces than for Materials. A material is named '*dark*', '*hard*', '*heavy*', '*warm*', '*opaque*' or '*bluish*' when described by the interviewees. An element is rather characterized as '*big*', '*long*', '*curved*' or '*high*'. And a space can be '*large*', '*open*', '*low*' or '*rectangular*'. There are some exceptions where a material is called a '*thin*' or a '*thick*' material

and a space is noted for its *'darkness'* but in general we can say that the physical behavior of the material refers to the physics of the matter (e.g. texture, mass, color) and the physical behavior of elements and spaces refers to their geometry (e.g. shape, size).

This seems a reasonable finding as a material in itself has a certain surface geometry but does not have a size or shape in itself. When a material is directly linked to a geometry aspect, it is actually in reference to the manufacturing technique (*'concrete would be like that thick'*) or the structural behavior of the material – what *can* we do with this material? – and thus indirectly to the final element. Reversely one can hardly speak of the (physical) coldness or softness of a space without associating a material to it.

The physical behavior/appearance can thus be divided into two larger subgroups: geometry aspects (size, shape and volume) and physical attributes (technical and sensorial aspects).

## **Experience**

The interviews show that a material can also be described according to 'Associations', 'Personality' and 'Emotion'. Descriptions such as *'brick red'*, *'airport-like'* and *'Norwegian'* are associations made to things, aspects or situations that are familiar to most people. Words that are used to describe the human characteristics of a material, such as *'clever'*, *'funny'* and *'simple'*, are categorized under 'Personality'. The theme 'Emotion' contains words that express a certain level of emotion elicited from the observer, such as finding a material *'lovely'* or *'off-putting'*.

In general the experience-vocabulary is extensively used to describe Spaces. More than half of the vocabulary used to describe a space is related to the experience of the space.

In terms of associations, we find references to the origin of the materials: *'Norwegian'* or *'African'*. The associations made for spaces relate to familiar spaces and uses of spaces (*'domestic'*, *'living-room-like'*) or to styles (*'baroque'*, *'modern'*). The words used to describe a personality are very similar for materials and spaces. A material can be *'brutal'* and a space can be *'brutal'*. Similarly subjects mention *'friendly'* materials and *'friendly'* rooms, or *'formal'* materials and *'formal'* spaces. The question remains whether a space is formal because formal materials are used, or whether a material is perceived as being formal because it is often used in a formal setting.

Elements are rarely described in terms of experience. This finding makes sense as it is hard to imagine how to experience an isolated architectural element but rather easy to imagine how to experience a space or a material.

## 4. 2. ITERATIVE THOUGHT PROCESS

Rather than thinking in terms of materials, we could say that architects are constantly switching back and forth between the desired 'attributes' of the space (=atmosphere) and the 'attributes' of the materials (=material attributes). It was noted that aspects related to material choices and properties are often also related to the desired or existing aspects of the space. The complexity of this decision process and the complex relationship between material-element-space is illustrated by discussing one particular design decision in one of the interviews in-depth.

The following paragraphs aim to lead the reader through part of the interview and reveal some of the issues that arise around material choices through the use of specific examples. These examples reveal only a small fraction of the vast amount of nuanced information that is available in the data, but give some insights and already provide plenty of matter for discussion.

Within the discussion of the excerpts the codes {P}, {E}, {F}, {C} and {M} are used to refer to, respectively, the domains of Physical behavior, Experience, Function/Use, Context/Environment and Manufacturing process. The interview time of the excerpts is marked as [hh:mm].

The interview passages displayed in the following section focus on the material choice process for two large exhaust elements in the lobby space of a law school. At first, the architect considered the use of wood, but in the end the exhausts were executed in plaster. During the interview the architect reflects upon that decision and considers some alternatives and their possible impact.

### **From existing experience of space towards material choice**

*[S1 00:13] It was all very cold. I mean it really is just a very ... uhm... really unfriendly, very cold in its aesthetic and everything, and just... So we wanted wood in there.*

Starting from a specific situation – the space being very cold {E} and unfriendly {E} – the architect looks for something 'warm' {E}{P}. Without making this aspect explicit, the reference is made to wood because people tend to think of wood as being warm {E}. An attribute thus can be related to the space but be reflected in the material choice. This shows that an experience {E} for a space – such as 'cold' – can be reacted towards by applying a material that has 'warm' properties {P}.

*[S1 00:13] We actually did not end up with wood; we ended up with plaster, colored plaster.*

The explicit specification for 'colored' plaster {P} indicates that the physical attribute 'color' is a crucial aspect on the experience {E} of warmth and friendliness for the space. S1 continues, "... we wanted some color in there. We do not really did get it in here. But we wanted some warmth". Color helps with making the space more friendly and less cold.

### **From interaction with users towards material choice**

*[S1 00:39] The idea behind the wood was that it would, it would be next to you. In other words, the wood would be what you would touch, and what you would lean up against, and what you would lean on.*

The choice for the material is made based on the immediate interaction of the user with the material {P}{F}. In architecture, not all surfaces can be touched and not all surfaces are meant to be touched. At another point S1 mentions that people are "pushed away" from a stainless steel wall; it does not really ask or long to be touched. The immediate sensorial aspects of the material {P}, including those aspect related to the touch, play a role in the decision making process for choosing materials in architecture. In this example a material is chosen for its specific (sensorial) physical aspects {P}, which have an effect on the immediate sensation of the material {P} by the user, as well as the use of the element {F} within the project.

### **From intended experience for space towards material specification**

*[S1 00:07] [...] So we thought, when you come in here what you want is the feeling of having arrived in a... the feeling of light. Lightness and light. So, light in terms of being luminance but lightness in terms of 'not feeling the weight of the building on you'. [...]*

*[S1 00:33] [...] What we uhm... the colors were really important. [...] we were thinking in a very blond way. So the feeling was a sort of Norwegian, uhm a Northern European blond and the hard surface are more glass and metal.*

Even though the choice to go with wood was rejected along the way, the color would have been an important attribute in the material choice. In the first excerpt [S1 00:13] it was found that color {P} is a material aspect that is used to influence the personality (coldness and friendliness) of the space {E}. At this point the desired 'lightness' {P} of the space defines the color 'blond' {P} of the material. A desired physical aspect {P} for the space is thus achieved through specifying the physical attributes {P} of the materials.

A reconstruction of the lines of thought (Lawson 1994) shows that the choice for wood is made as a first reaction to the coldness of the space – space defines material. Secondly the chosen material is specified in terms of colors (blond) in order to create the desired effect (lightness) – material color influences space. A constant switching back and forth between space and material does occur during the design process, often related to switching from aspects from the ‘experience’ domain {E} to the ‘physical’ domain {P} and back.

### **From material specification towards association and physical behavior**

In the last excerpt [S1 00:33] the association {E} that is made to the origin of the wood – Norwegian or Northern European – is related to a feeling {E} as well as to the color {P} itself. In this sense the associations made with the blond woods in Scandinavia help in describing the experience of the space, as well as the physical aspects of the wood (color).

The fact that the specification of the wood at this point is specified by an association (Northern) {E} rather than by its specific type (maple) {P} indicates that the material choice is still situated at a rather conceptual level.

### **From experience of space towards assembly and manufacturing of an element**

The architect continues that using wood in that particular area would have “compelled them to think about style”.

*[S1-00:19] Formal. We wanted it to be formal because it is a law school and this law school competes with lots of other law schools for students. So it had to have the regularity, well formality. So the forms were all thin lined up very carefully in a very... uhm... modernist way.*

S1 wanted the space to be formal {E} because of the function of the building (law school) {F}. The regularity and formality {E} is reflected through carefully lined up forms {M} and clean lined materials {P}{M}, put together in a modernist way {E}.

*[S1-00:19] [...] That is kind of the modernism part of the work, so these pieces speak to the function of the building but they get clad in very, very clean lined materials so you can make the connections between materials very minimal. Any connections between panels were very simple reveals.*

*[S1-00:33] [...] This is a... I think if it were wood... How would that have affected it? It would have compelled us to think about style. That would be one thing because having a lot of wood that is... that would fit into this language... so very planar, very*

*unadorned, uhm I am not sure would have helped make a difference with the hardness of the space. I think maybe a little bit. [...]*

The projected formality {E} for the place is related to a modernist way of thinking and is reflected in the assembly of the materials {M} as well as the physical properties of the materials {P} themselves. Even though we might think of wood as a material to soften {E} a space, we can specify the material and its assembly in such a way that it still has a certain hardness {P} to it – a hardness in color {P}, a hardness in ornamentation {E}, a hardness in assembly {M}. In a way the architect suggests here that there is a certain level of hardness to modernism.

### **From experience of a material towards physical attributes of a material**

Looking at another passage in the interview where S1 compares the dark mahogany wood used in the informal lounge space upstairs to the light maple applied in the formal entry lobby, S1 is more explicit about how the maple fits better with the formal atmosphere.

*[S1 01:04] [...] This wood here, it still feels like... it is still, although formal, it is a little fragile. [...] the graining [from the maple] is definitely finer and lighter [than the mahogany]. So there is a delicacy to that but it is fragile because it is clearly a veneer. And laypeople do not know that, non-architects do not really know that, but on the other hand these are thin panels and they feel like thin panels.*

The finer and lighter graining {P} help to make the space look more formal {E}, but in the end it is the fragility (through the way of processing the material) {M} that really contributes to the formal look. The fact that the thickness {P} of the panels (element) can be seen, tells the user that it is a thin veneer. From experience one knows that – in contrast to a solid piece of wood - a veneer can be chipped off when something hits it {F}.

This section shows that the relations between space, elements and materials are very complex and diverse. A wide range of attributes are used for all three of them, and connotations – having a particular logic – help choosing materials or defining the character of the space or element. Why certain attributes are used and not others is not clear yet, but at least we could demonstrate the need for a thorough characterization of materials in order to be used in the decision making process in architecture. Therefore, we believe it would make sense to start structuring material information according to the thought process of the architect rather than to a structural scaling hierarchy.

## 5. CONCLUSIONS

Even though a lot of architectural reference books and systems are organized according to a hierarchy of materials, elements and spaces, we find that this hierarchy is not reflected in the design process. Architects do not think in terms of materials, elements and spaces but rather in terms of the experience they want to create and the attributes they need to create this experience. Within the thought process a constant iteration between the existing or intended experience of the space and the physical attributes of the materials is noticed.

Five primary domains could be identified to describe the different characteristics considered by architects during the design and material selection process: *'Physical behavior'*, *'Experience'*, *'Function/Use'*, *'Context/Environment'* and *'Manufacturing process'*.

The majority of words used to describe materials can be grouped within the domain of 'Physical behavior'. Most of these physical material attributes relate to the existing data provided for materials in the conventional databases or can be found in the specialized literature available on sensorial attributes. For some aspects, such as 'color' or 'texture', it is however desirable to define some architecture specific definitions.

In contrast to the physical behavior, more than half of the words used to describe a space belong to the domain of 'Experience'. The analysis of the interviews reveals that there is a strong correlation between the experience of a space and the materials that are applied in that space. At the moment, however, no information on these experience aspect of materials (in an architectural context) is available in literature.

Through further research we will investigate whether these experience aspects can be related to existing physical material attributes or whether new material parameters for architecture will have to be developed. The possible correlation between experience aspects and the physical material attributes will be studied by using techniques such as data sorting and cluster analysis. We believe that the physical attributes of materials contribute to the architectural experience in an objective manner and therefore can help in describing these experiences in a more objective manner.

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