EXPERIENTIAL APPLICATION OF RECLAIMED MATERIALS IN NEW BUILDING DEVELOPMENTS

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ABSTRACT

As the circular economy gets more and more attention it is needed to get the knowledge on closing material loops, especially in the building sector, where the materials contain a lot of embedded energy. Application for reuse of materials requires knowledge on the physical characteristics of the materials itself, but also on the possibilities for reuse of the existing building materials Together with this knowledge, people still should be able to get an aesthetic architectural experience in their build environment. In search of a proper application of the reused materials as experience, the vocabulary of experiences creates an understanding in the interaction between people and building. In this research a toolbox will be proposed to connect the materials experience with the application to reuse materials, coming from the existing, to be demolished, buildings of the Amstel III area in Amsterdam. The toolbox will provide a method for designers to apply the reclaimed materials in the desired experiential architecture.

KEYWORDS: *Upcycle, Recycled Materials, Materials Experience, Reuse, Experiential Application*

1. INTRODUCTION

The recent energy savings and sustainable transition ask for a new approach in the economy; a circular economy. As stated in the Upcycle Amstel book, it is most valuable to consider the reuse of existing embedded building materials and design for disassembly.[1] Materials in buildings have two overlapping rules: they provide technical functionality and they create product personality.[2] To have these two functions fully implemented in a building's existence it is of importance to get to know the value of those both rules. A product, or in this case a building, personality will be created with a specific experience. And while experience will be made by materials, materials will have an influence on the experience. Materials react with one another and have their radiance, to that the material composition gives rise to something unique.[3] This uniqueness can be described in users' experience of the building, where the experience of a building is constructed with reclaimed materials from the area around it and gives a meaning to the value of the building and the circular thought. As the barriers to reclamation and recycling are the unfamiliarity of people what solutions could be,[4] there is a need to show it to the people, the mass, that the circular approach is needed where materials are a great deal. People should get hands-on with the approach to apply it in daily use. However, the question arises how this topic could be brought to the people. As an experience of a space or object will be remembered by people, the question in this research is; *How can reclaimed materials from the Amstel III area be applied again in (partly) new buildings where they can contribute to the experiences and adaptations of the users in a cultural building*. In this case, exploration of how people could participate or be aware through the circular experience or reused materials will be done.

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[1] Dekker, E. Gao, Q., Lukkes, D.A., Markus, F., Bohle, M. (2018) p.26
[2] Ashby, M. (2010), p5
[3] Zumthor, P. *(2003)*, p25
[4] Addis, B., (2006) p. 7

1.1. Experience design

As for both the materials and experience will be important, three aspects will be explored: which materials are available after demolition of the buildings in Amstel III, what are the characteristics of the materials derived from these buildings and which experience of materials is perceptible. As to explore the material experience it requires to qualify not only the physical characteristics of the material but also what the material expresses to us, what it elicits from us and what it makes us do.[5] Research into this area of material experience is needed for architecture, as there is no such thing yet of a material database where one can find the emotional/experiential characteristics of a material, where the designer can base their choices at while designing. In this research therefore a study into both aspects of material physics and experience will be explained. The focus in this paper will be on the aesthetic, sensorial experience of the building materials, as for the experience will mostly be perceived by the human senses, combined with the physical characteristics to be able to reuse the materials.

1.2. Method

As the result of this research will be a guidance toolbox for designers to implement experiences of materials with the reuse of reclaimed building materials from the Amstel III area, the available amount of materials from the demolished building will be analysed. This part of the research comes from the Upcycle Amstel booklet of the studio group, where in collaboration with Metabolic numbers of the amount of materials are gathered. In order to explore in which way these materials could be applied in new developments, a literature study substantiates the possible examples for appliances of reclaimed materials. As for design involves choice, normally from an enormous range of data and ideas,[6] a toolbox will be the guideline for designing appliances of reclaimed materials, were the focus will lie on which experience these materials will bring into the architectural design. To explore the appliance of experience, the methods of Material Driven Design, of Elvin Karana, is used to form a language for materials experience. The method, developed in the environment of Industrial Product Design, has been chosen as there is scarcely written about in the context of architectural design, and these are one of the first steps in Industrial Design of designing with materials.[7] Three experiential components will be explored in materials experience; the aesthetic experience (which is sensorial) the experience of meaning and the emotional experience. Together they form an overview for the toolbox. After the research into the various experiences, a material experience vision can be created by analysing case studies. However, as this will involve design, this will be done in further and the methods of the toolbox will be tested through the examining of the case studies.

2. From waste to experience

As to design with reclaimed materials, knowledge is needed about the materials specific characteristics how they can be applied. Appliance of the experience will have the greatest capacity to end up with aesthetically reused materials. Before any experiential values could be given, the materials which to apply need to be known. In table 1 an overview is given of the materials available for reapplication found in research and also the materials which are available in the area, investigated by Metabolic. There are quite a few corresponding materials to work with. The main difference will be the appliance of the material, however, as this research focusses on the materials itself we can relinquish these differences.

[5] Karana, E. (2015) p. 35
[6] Ashby, M. (2010) p. 124
[7] Karana, E. (2015) p. 36

Table 1 Comparing materials to reuse in general with materials available in area of Amstel III

Material families/from literature	In Area Available from Metabolic
Concrete	Concrete
Glass	Glazing
Ceramics	Sand and ground
Metal: Steel	Bricks, stone, ceramics
Metal: Aluminium	Gypsum
Metal: Copper	Steel
Stone: bricks	Copper
Wood: multiple applications	Wood
Plastics	Plastics
Textile	Bitumen

2.1. Inventory possible reusable materials

In this case study of Amstel III, the first numbers of the amount of materials were gathered in collaboration with Metabolic, they developed a system to calculate the amount of materials in an existing building. Table 2 shows the collected numbers of materials which are available in the area, an expanded table can be found Appendix A. To check if these numbers were sufficient for this area and applicable on each building a case study was done into one of the buildings in the area, Hullenbergweg 1-3. By analysing the building plans, going to site, take photos of exterior and interior and making of a 3D model more precise numbers were found, see figure 1.[8] Comparing the values of the case study with the values of Metabolic we see grreat differences for some materials, mostly due to the fact that in the case study only one building was analysed and multiplied to the whole area of Amstel III, while Metabolic uses formula's to identify the numbers. However, for this research, not the exact amounts are needed to explore the usability for materials experience, therefore the Metabolic values will be the guideline further in this research.

Table 2 Available amounts of materials in area, numbers by Metabolic, gathered through Merlijn Blok and Upcycle Amstel

Material	Amount Metabolic	Amount Upcycle Amstel
Sand and Ground	53,536 tons	50.000 tons
Concrete	181,224 tons	70.500 tons
Bricks Stone and Ceramics	11,242 tons	10.500 tons
Glass	802 tons	750 tons
Gypsum	4,638 tons	1.025 tons
Steel	1,874 tons	1.750 tons
Copper	12 tons	-
Wood	2,408 tons	-
Plastics	131 tons	(Polystyrene) 112 tons
Bitumen	936 tons	875 tons

2.1.1 Available materials

When looking at the amounts of materials available in the area, one cannot guess in which form they will be found inside the existing buildings. These numbers only give information of the materials, rather than the components in which they will appear in the buildings. As for the amount of materials, a lot of concrete (181,224 tons) is available, probably casted in situ. Due to the recent changing trend of making concrete demountable,[9] all of the concrete applied at site will

[8] Dekker, Gao, Lukkes, Markus, Bohle (2018) Upcycle Amstel p. 64-71
[9] Jensen, K.G. Sommer, J. (2016)

be casted concrete. Even if standardized prefabricated components are used, they were mostly covered with a layer of casted concrete to connect it together.[10] In this case, concrete will be the

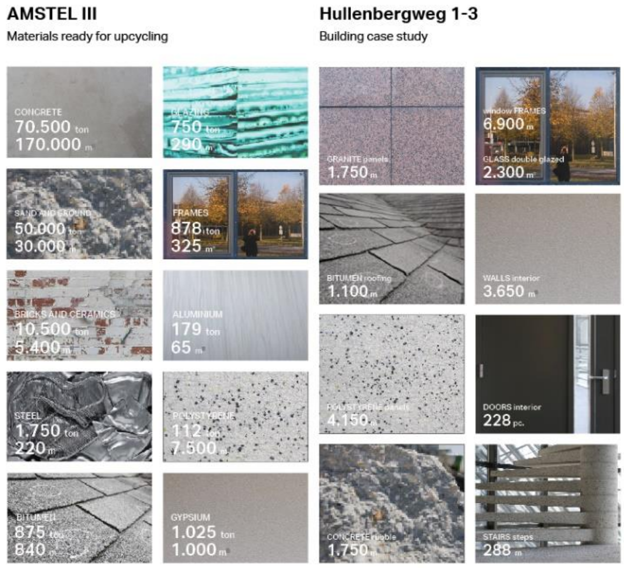

Figure 1 Available amounts of materials in area by case study (also in appendix B)

most promising material to reuse, concerning the reduction of the environmental impact.

2.2. Reuse possibilities of reclaimed materials

Looking at figure 1 the overall feeling gathered from the materials is very gloomy, the colours are mostly grey, there are mirroring surfaces and all flat façades. Opportunity in this area lies in the fact of reusing these materials, by giving it a different atmosphere than it does nowadays in the existing buildings.

2.2.1. Physical characteristics of materials

In order to have materials available to make something 'new' from it, the materials need to be separated from each other during the demolition phase. As for metals are easily separated, if not applied with casted concrete, with electromagnetic methods these materials are already highly recycled in the metal production. Around 90% of the metals, mostly steel and aluminium from buildings, are reclaimed and returned to production plants, where mixed again with virgin metal it becomes 'new' materials.[11] However, not for all materials this separation process is as easy as it is for metals, where the opportunity lies in the separation of the demolition process. If demolishers will spend time and money on separating the materials during the process, environmental benefits can be reached and costs can be equalled with the selling of these materials.[12] Where the costs of the separating will be levelled with the profit of the selling. Before being able to notice which potential a material could bring when reused as building materials, knowledge of the physical characteristics is needed for the options to reuse. Table 3 shows a summary of the most important physical properties of materials in general. A more detailed table is placed in Appendix C.[13]

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[10] Addis, B. (2006) chapter 5
[11] Addis, B. (2006) p.6
[12] Deker, Gao, Lukkes, Markes, Bohle (2018) Upcycle Amstel
[13] Based on materials described in Kula, D., Ternaux, E. (2014) and Addis, B. (2006)

Table 3 Physical characteristics of materials

Materials	embodied energy:	Density (In kg/m3)	Composition	Corrosion	Properties
Concrete	3 GJ/t	very light: < 500 light 500-1800 heavy 1800-2500 very heavy > 2500	7-15% cement 60-70% aggregate water, admixture and air	only when metal is added	Great in Pressure; tensile strenght limited fire resistant; non-flamabe Durable
Glass	30 GJ/t	2.5 kg/m3	Silicia, as sand (Oxides) Stabaliser Additives	-	Transparant Isotropic Good recycleble
Ceramics	Tiles: 3 GJ/t			-	Low maintancance
Metals	45-100 GJ/t				
Steel	high energy cost in manufacture (but recyclable)	7850 kg/m3	FE + C	Mediocre	hard Resilient Elastic Plasticity Ductile Isotropic
Aluminium		2700 kg/m3	Al	very tollerant	
Copper		8800-9250 kg/m3	Cu	most vulnerable	
Stone: Bricks	3 GJ/t				
Wood		dependend on wood specy defined in relative densifty, hardwood is 1	Lots of species	-	Viariable durability, dependend on species, treatmenst Lightweight, yet extremely advanced
Granite		3000 kg/m3	Feldspar Micas quartz	-	Resistant to wear polishes very well

2.2.2. Applications to reuse materials

For the materials described in the overview several options for reuse are applicable, all with its own positive and negative result. Also the possibility to reclaim each material from construction site plays a role in the possibility to reuse them in a new project. For a few material families some general rules of gathering and appliance concerns the following characteristics. In figure 2 an overview of pro's, con's and appliances can be found for each material.[14]

Materials	Pro's	Con's	How applicable again	Remarks
Concrete	structural strenght if reused in its total form, more sutainable by time cheap	Uses a lot of energy to produce if casted on situ difficult to reuse most prefabricated parts are casted together process in (up until now) irreversible	crushed in parts for aggregate for new concrete reuse elements of precasted; only with dry connection if demountable cut casted concrete into pieces for reuse	great environmental impact by production
Glass	doesn't decay robust enough to be removed, cleaned and reus	remelting is an intensive process for energy use will have a lowe perfomrance specification than requiredm concerning transmission perfomance, reflectivity and emissivity	Remelting single-glazed panels cut panels into smallers pieces and use for new panels thoughened glass, coated glass only available for reuse is the panel keeps its form	whether or not it can be cut to size One of the easiest material to recycle (if not mixed)
Ceramics				
Metals	easy seperated by electromagnetic methods panels: easily cut to shape and machined to suit new fixings	if welded together difficutl to tear apart If casted in concrete difficult to take apart	Easily gathered with electormagnetics on site can be remelted with partly virgin metal to create new product	requires great deal of energy to recycle (due to melting) can be easily repaired
Steel			If metal product still fulfills requirements, fully reused, as construction can be adopted elemnts of construction can be taken apart, if joints are dry connected, otherwise joint part can be cutted off	90% of used metals are already recycled
Aluminium Copper			panels easily reused with ne finisg, easy adaptable to new sizes remelting into new parts	
Stone: Bricks	easy material to work with traditional, everybody knows how it works	masonry with cement morter not demountable	can be seperated from morter, cleaned and reused (only with lime orter) if cement morter, parts of wall can be cutted into smaller pieces) new bricks can be party made of recycled content	Dependend on the ease individual bricks can be seperated and cleaned before 20th century easy to take apart due to lime mortar, later on uses cement
Wood	environmental neutral, if not threathened can be cut into smaller pieces easy construction when in good conditio, panels can be reused	if coated bad environmental impact quality of wood can be bad, if not threathend well panels not practical to refubish eijter for reuse	cut into smaller pieces cutted into chips for chipboard, OSB, MDF returend to earth for soil improver	if contained as long as possible in its original solid wood state more stustainable by time to regrow new trees
Granite	degrade little in use easily removed from buildings Low risk of damage			Generally in demand opssible to fit with bespoke fixing to suit a new cladding system

Figure 2 Material pro's and con's and the reuse availability

The most important part of this study is to look at how the materials can be reclaimed from the demolition site and what quality it still has. This can only be known for each project individually, only by analysing the building, one knows how much of the original materials can be reused. If one is trying to make the most environmental profit out of the reuse of material, it is best to look

[14] Addis, B. (2006)

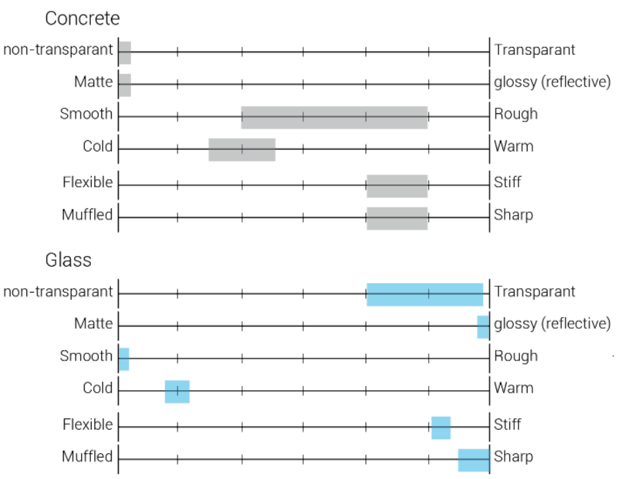
at how much embodied energy the material has, as in table 3 is visible metals, have the most embodied energy and thus have the most environmental profit to reuse in its state where it is found. For all materials made into standardised sizes, applies the fact that cut joints will make it difficult to apply standardised façade elements, as they are based on standardised dimensions.[15]

2.3. Experience of materials

How reused materials will contribute to the new architecture in their full extent will depend on how people appreciate the materials. Therefore the experience of the materials count. In architectural research there is not much written about experiences, but when it is mentioned it always contains the materials contributing to the experience. To define this description of materials experience a vocabulary is used to structure material groups. This is sufficient for describing spaces an experience-vocabulary is used, where experience can be reacted by applying materials that have the desired properties.[16] Spaces define materials, and materials influence space, where we perceive atmosphere [experience] through our emotional sensibility.[17]

2.3.1. Vocabulary on experiencing materials

How can you tell what a material is, or how it will be experienced? Therefore a vocabulary is needed as the experience of a material is highly individual, while a vocabulary can make it common and explainable.[18] In the method of Material Driven Design of Elvin Karana, four experiential levels are given to describe materials experience. The vocabulary used to describe the experiences in this research is based on this principle, where understandings of experiences are based on *sensorial, interpretive, affective* and *performative* levels. These levels are highly based on the personality of a product, or in this case a building(element), because when people experience something, it includes emotions the users have when they interact with it.[19] The best way to identify the experience with the users' associations is by means of emotions and senses they give to the building's personality.



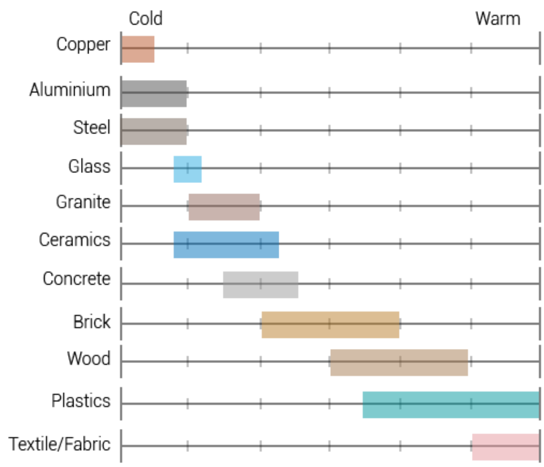


Figure 4 Sensorial Experiences of Concrete and glass

Figure 3 Senses of Cold-Warm in material order

Firstly the sensorial level is explored for the common materials, the vocabulary is based on the human senses to measure the experiences of each material. Contradicting pairs of senses are chosen to map the materials. With the contradicting pairs, differences can easily be found between

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[15] Addis, B. (2006) p 121
[16] Wastiels, L (2007) p.10
[17] Zumthor, P. (2003) p.13
[18] Wastiels, L. (2008) p.8
[19] Van Kesteren (20..) p.1

materials, where the sensorial contrasts give attention to the nature of the materials.[20] The grouping per pair of senses shows the designer a tool of which material to use when designing for each experience. In appendix D a full overview of the materials can be found, figure 4 visualises the maps for concrete and glass and figure 3 the senses of cold-warm. Figure 5 gives an overview for which couples can be compared in the focus of sensorial experiences. From this list, a designer can pick the senses suitable for his/her project to map out the sensorial experiences

Following the steps into the interpretive level will give a more defined idea of the experience by the meanings users give to the material. Words which could be used to define the material for the user's association with the materials are listed in figure 7. As for figure 8 provides words to describe the affective level. This level describes the emotion people feel while experiencing the materials and the associations they have when interacting with the materials. The affective level is mostly dependable of the user's own emotions and feeling at that time. Together these levels form a vocabulary in which a toolbox can be formed to describe experiences and connect them to materials and vice versa.

This vocabulary is used to get from the physical properties and meaning of the materials to the experiential meaning of the materials. However, these reactions differ from person to person and can also be influenced by their moods, preference and culture, which makes this a highly subjective way of defining.[21] From this vocabulary, a toolbox is created in which a designer can easily find the reuse applications for materials, its sensorial experience and the words forming the interpretative and affective level. Which are based on the description of the four experiential levels of Karana, described in foundations of Materials Experience.[22] Figure 9 presents a part of the toolbox for the materials of Concrete, Steel and Aluminium, the complete table appears in Appendix E.

Touch		
	Smooth	Rough
	Soft	Hard
	Light	Heavy
	Cold	Warm
	Flexible	Stiff
	Weak	Strong
	Ductile	Tough
	Nong elastic	Elastic
Sight		
	Non-Transparant	Transparant
	Translucent	Optically clear
	Matte	Glossy
	Non-reflective	Reflective
	Smooth	Textured
Hearing		
	Muffled	Sharp
	Dull	Resonant
	Low pitched	High pitched
Smell/Taste		
	Bitter	Sweet

Figure 5 Sensorial vocabulary

Interpretive	
Aggressive	Passive
Cheap	Expensive
Classic	Trendy
Clinical	Friendly
Clever	Silly
Common	Exclusive
Decorated	Plain
Delicate	Rugged
Disposable	Lasting
Dull	Sexy
Elegant	Clumsy
Extravagant	Restrained
Feminine	Masculine
Formal	Informal
Hand-made	Mass-Produced
Honest	Deceptive
Humorous	Serious
Irritating	Loveable
Mature	Youthful
Modern	Traditional
Nostalgic	Futuristic

Figure 6 Interpretive vocabulary

Affective	
Amazed	Calme
Surprized	Expected
Bored	Joy/Exited
Disappointed	Pleased
Disgust	Like/Admiration
Hate	Love
Annoyance	Satisfaction
Fear	Faith
Vigilance	Impulsive
Pensiveness	Confidence
Optimism	Disapproval
Hope	Unbelief
Anxiety	Outrage
Despair	Pride
Awe	Aggressive
Cynism	Curiosity
Delight	Pessimism

Figure 7 Affective vocabulary

The toolkit describes steps to take for the reuse of materials to apply them in the desired experience for the new architecture. The designer can approach this toolbox by first creating the design criteria for which experience is needed, as experience contains our emotional sensibility, these would be described by the same sensorial, interpretive and affective words as can be found in the toolbox. After this step, the designer can compare the experience vocabulary of his own design brief and the ones in the toolbox to find materials which match the desired experiences.

[20] Karana, E. (2015) p. 41
[21] Wastiels, L. (2008) p.8
[22] Giaccardi, E., Karana, E. (2015)

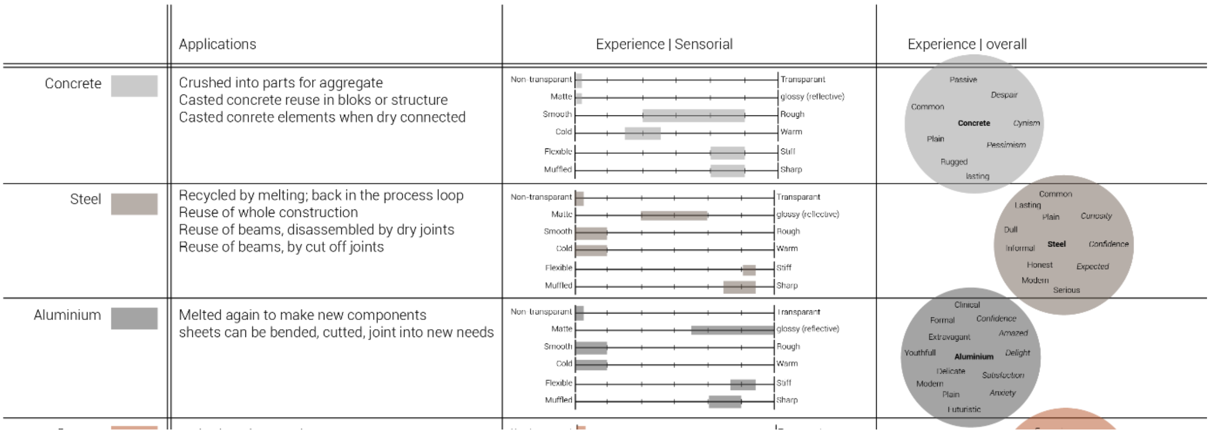


Figure 8 Part of Toolkit diagram

3. Conclusions

3.1. Discussion

The created tool for material experience will give new opportunities for architects who focus on architectural experience design, the opportunities will include helping them to make choices based on the intended experience, where reused materials will make this experience possible. In this research, the experiential intentions of the material itself are made possible by taking the steps of naming the sensorial, interpretive and affective level, where the designer is able to create a database, project specific, of all the materials available in the area contributing to the desired experiences of the project. The toolbox is not only applicable on reused materials, but it also can involve applying it to new materials with the wanted experience, however, this toolbox will motivate designers to reuse materials from a near location to reduce the environmental impact of the building sector. As the methods express a vocabulary which can be used to describe an experience, further research will be done into the outcome and validity of the method by analysing and qualifying the perceptible experiences case studies which are built up by reused materials. Examples are Hof van Cartesius in Utrecht, Circl pavilion in Amsterdam Zuid, De Ceuvel in Amsterdam Noord, Noorderparkbar in Amsterdam and the People's Pavilion. However, most of these projects contain not only reused materials, but also components, the only adaptation to make and have further research is the application of these components the description of the experience can act in the same method. As the exploring of the experiential levels is done particularly on this case study of the Amstel III area, and a designers personal view on the experience of materials, further development of the method can be done when a survey will include more people quantifying their experiential feeling with the materials, in that case, a more throughout exploration can be done into the general perception of materials experience.

3.2. Conclusion

Coming back to the question at the start of the research, *how reclaimed materials can be applied again in a new building where they contribute to the experience of the users*, a toolbox was developed to get from the material level to the experience level. In this toolbox, considerations can be made whether the materials will contribute to the wanted experience, given by the design brief and whether it is sufficient to reuse the materials again in a new building. The reuse abilities in this tool are based on the principle of design for a circular economy, for which in-depth research is done for the booklet of Upcycle Amstel for the circular symposium. The toolbox derived from bilateral research into the possible applications for reused materials and the how materials can be experienced in an architectural context. The selected materials are based on the availability in the area of Amstel III, which has the ambition to transform in a circular way. The framework will contribute to the application of all the unused materials of demolished buildings nowadays.

4. References

Literature List

1. Kula, D., Ternaux, E. (2014). *Materiology* Basel: Birkhäuser Verlag GmbH
2. Addis, B. (2006) *Building with Reclaimed Components and Materials; A Design Handbook for Reuse and Recycling, London: MPG Books Limited*
3. Ashby, M., Johnson, K. (2010) The Stuff… Multi-Dimensional Materials. In: *Material and Design*, 2nd ed. Butterworth-Heinmann
4. Giaccardi, Elisa & Karana, Elvin. (2015*). Foundations of Materials Experience: An Approach for HCI.* Proceedings of the 33Rd SIGCHI Conference on Human Factors in Computing Systems.
5. Karana, E., Barati, B., Rognoli, V., Zeeuw van der Laan, A. (2015) Material Driven Design (MDD): A Methods to Design for Material Experiences, in: *International Journal of Design, 9(2), 35-54*
6. Wastiels, L., Wouter, I., Lindekens, J. (2007) Material Knowledge for Design – The Architect's Vocabulary*, in: Emerging trends in Design Research, International Association of Socieies of Design Research (IASDR)* Conference, Hon Kong, Hong Kong, 2007
7. Wastiels, L., Wouters, I. (2008) Material Considerations in Architectural Design: A Study of the Aspects Identified by Architects for Selecting Materials, in: *Undisciplined! Design Research Society Conference 2008,* Sheffield Hallam University, Sheffield, UK, July 2008
8. van Kesteren, IEH, Stappers, PJ & Kandachar, PV (2005), Representing product personality in relation to materials in a product design problem. in R Mazé (ed.), *In the making: 1st Nordic design research conference.* s.n., S.l., pp. 1-9, In the making: First nordic design research conference, Copenhaven, Denmark, 29/05/05.
9. Zumthor, P. (2006) *Atmospheres*, Basel: Birkhäuser
10. Dekker, E., Gao, Q., Lukkes, D.A., Markus, F. Bohle, M., (2018) Upcycle Amstel, 1st ed, for Symposium The Circular Built Environment, Anatomy of the AMC, Delft November 2018
11. Jensen, K.G., Sommer, J. (2016) Building a Circular Future, 3rd ed.

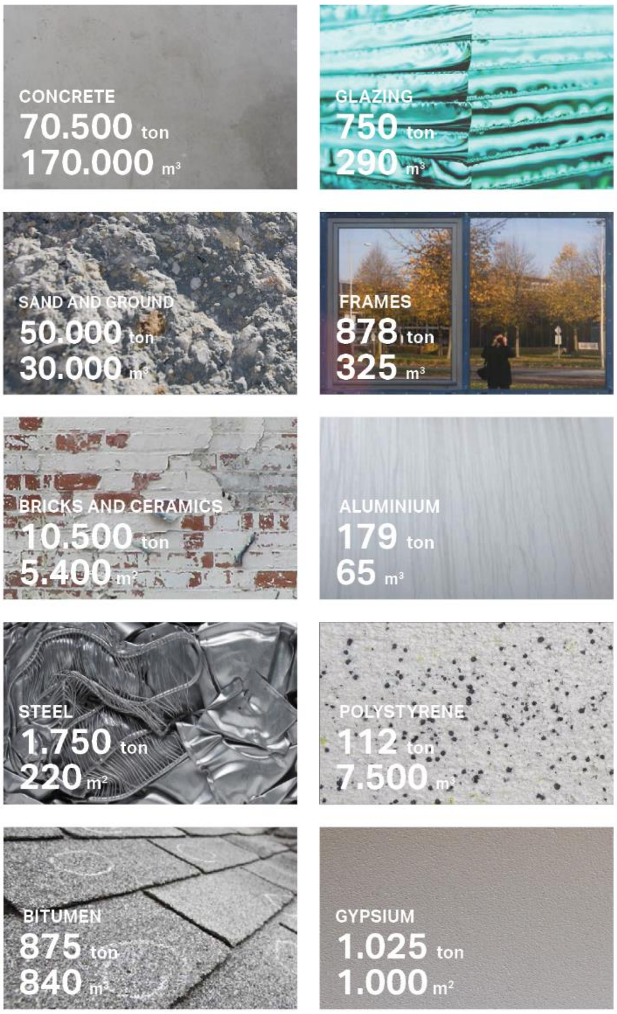
5. Appendix

A. Amount of materials available in area of Amstel III numbers obtained thorugh Merlijn Blok

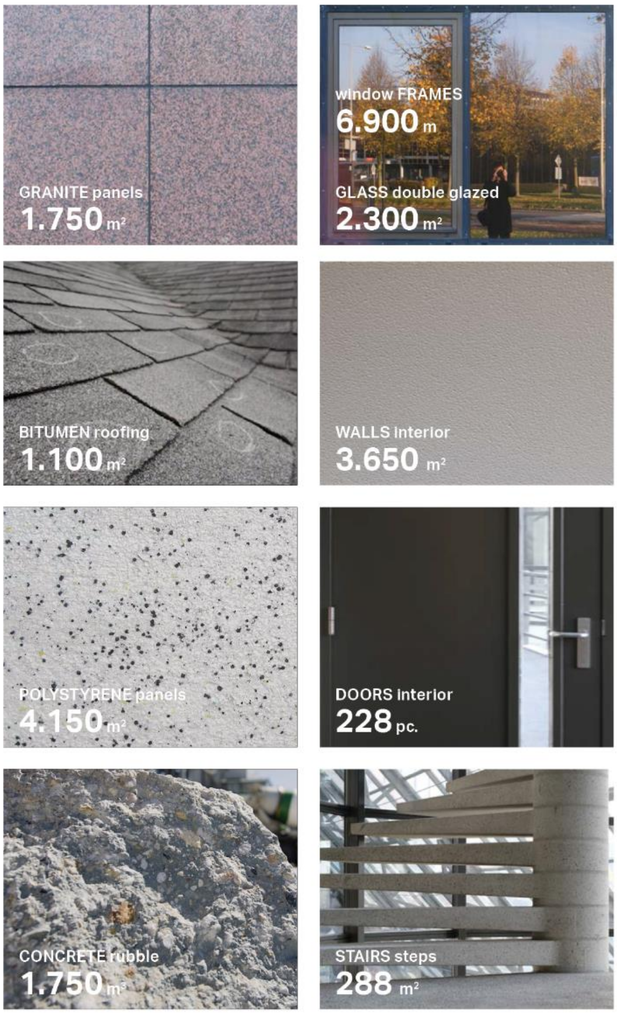
Building NO.	Address	Function	BVO/GFA (m²)	Building Year	Sand and ground	Concrete (ton)	Bricks, stone and ceramics (ton)	Glass (ton)	Gypsium (ton)	Steel (ton)	Copper (ton)	Wood (ton)	Plastics (ton)	Bitumen (ton)	Building Height (m)
					Expected material stock										
1	De Corridor 2	Café	761	2001											7.2
2	Hoogoorddreef 60	Office	6699	*1988*	2680	9070	563	40	234	94	1	121	7	47	39
3	Hoogoorddreef 62	Office	6034	1988	2414	8170	507	36	211	84	1	109	6	42	28.5
4	*parking space*	-	-	-											-
5	Haaksbergweg 4	Office	14367	*1992*	5747	19453	1207	86	503	201	2	259	14	101	-
6	Hogehilweg 5	Office	3320	*1984*	1328	4495	279	20	116	46	0	60	3	23	20
7	Hogehilweg 7	Office	2157	1984	863	2921	181	13	75	30	0	39	2	15	17
8	Hogehilweg 15	Office	3743	1984	1497	5068	314	22	131	52	0	67	4	26	23
9	Hogehilweg 13	Office	2091	1985	836	2831	176	13	73	29	0	38	2	15	16.4
10	Hogehilweg 6	Office	2951	*1987*	1180	3996	248	18	103	41	0	53	3	21	20.5
11	Hogehilweg 8	Office	5425	1987	2170	7345	456	33	190	76	1	98	5	38	30.5
12	Karspeldreef 4	Office	7805	1991	3122	10568	656	47	273	109	1	140	8	55	26.6
13	Karspeldreef 14	Office	7398	1990	2959	10017	621	44	259	104	1	133	7	52	30.3
14	Karspeldreef 16	Fire Dept.	4596	1990											30.3
15	Hullenbergweg 1	Office	5465	1988	2186	7400	459	33	191	77	1	98	5	38	16.5
16	Hondsrugweg 50	Office	4443	1988	1777	6016	373	27	156	62	0	80	4	31	11
17	Hessenbergweg 109-117	Office	2324	1999	930	3147	195	14	81	33	0	42	2	16	10.8
18	Hessenbergweg 95	Office	1905	2000	762	2579	160	11	67	27	0	34	2	13	14.6
19	Hessenbergweg 73-83	Office	2556	2000	1022	3461	215	15	89	36	0	46	3	18	10.7
20	Hettenheuvelweg 26	*Company*	1578	2008											7.3
21	Hessenbergweg 10	Office	2042	1987	817	2765	172	12	71	29	0	37	2	14	7.5
22	Hettenheuvelweg 14	Office	2367	1988	947	3205	199	14	83	33	0	43	2	17	14.3
23	Hettenheuvelweg 12	Office	3181	1988	1272	4307	267	19	111	45	0	57	3	22	14.3
24	Hettenheuvelweg 8	Office	2457	1987	983	3327	206	15	86	34	0	44	2	17	7.7
25	Hettenheuvelweg 4	Office	24024	1987	9610	32528	2018	144	841	336	3	432	24	168	7.7
26	Hettenheuvelweg 16	Office	2916	1989	1166	3948	245	17	102	41	0	52	3	20	17.4
27	Hettenheuvelweg 18	Church	1936	1987											6.8
28	*parking space*	-	-	-											-
29	Paalbergweg 3	Office	10016	1978	4006	13562	841	60	351	140	1	180	10	70	20.9
30	Paalbergweg 9	Office	16800	1982	6720	22747	1411	101	588	235	2	302	17	118	30.5
31	Paasheuvelweg 17	Office	2195	1991	878	2972	184	13	77	31	0	40	2	15	15.6
32	Paasheuvelweg 15	Office	1895	1989	758	2566	159	11	66	27	0	34	2	13	17
33	Paasheuvelweg 24	*Company*	1848	1991											6.5
Total					53,536	181,224	11,242	802	4,683	1,874	12	2,408	131	936	

Appendix B.
Material available in Case study Amstel III
Gathered from Upcyle Amstel booklet by Dekker, E. Gao, Q., Lukkes, D.A., Markus, F. Bohle, M.

Amstel III
Materials ready for upcyling



Hullenbergweg 1-2
Materials available

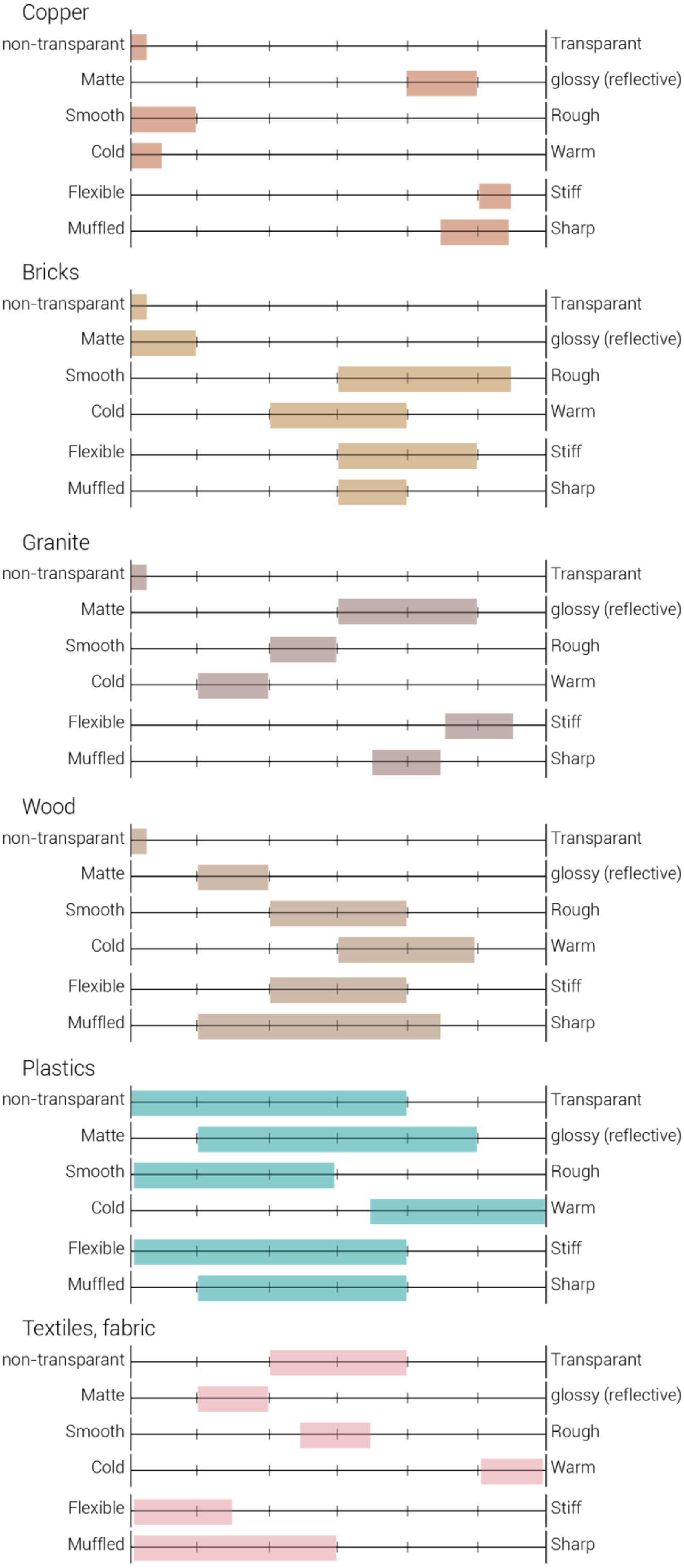


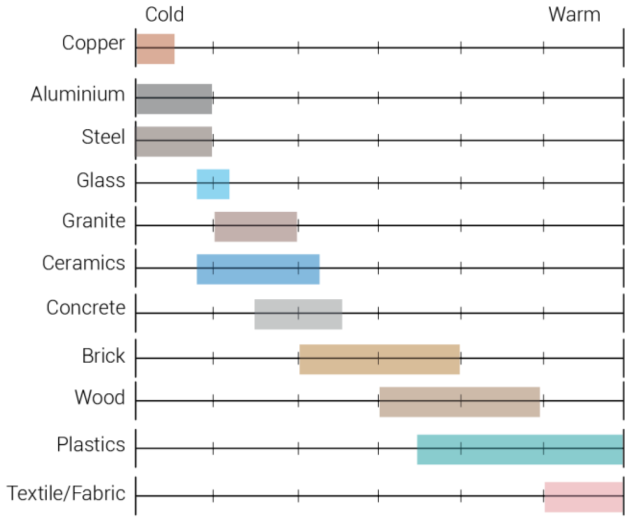
C. Physical characteristics of materials

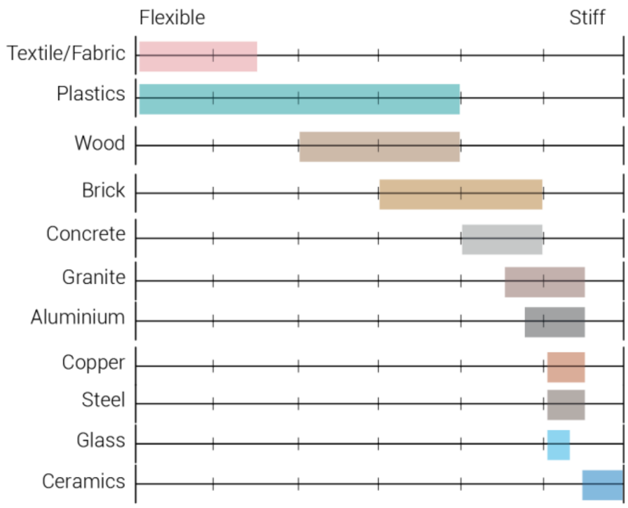
Materials	embodied energy	Density (In kg/m3)	Melting Point (in °C)	Composition		Corrosion	Properties		
Concrete	3 GJ/t	very light: < 500 light 500-1800 heavy 1800-2500 very heavy > 2500		7-15% cement, 60-70% aggregate water, admixture and air	cement: limestone and clay; a fired mineral powder aggregates: mineral - gravel or sand, expanded clay, glass pellets, recycled materials, wood chips, polystyrene Admixtures: imperative to the requiered qualities of concrete	only when metal is added	Great in Pressure; tensile strenght limited easily worked with; great freedom in form fire resistant; non-flamabe Durable Can be coloured with pigmet needs time to apply		
Glass	30 GJ/t	2.5 kg/m3	1800 °C	Silicia, as sand (Oxides) Stabaliser Additives	oxides; soada, sodium or alkaline lowers the melting point Stabaliser: lime makes it insoluble in water	-	Transparant Isotropic It slowly crystalizes; not in a men's lifetime Hard and brittle at ambient temperature When heated it becomes malleable and plastic Good recycleble; if not strenghtened or coated		
Ceramics	Tiles: 3 GJ/t						Low maintance strenght Does not scratch	Architectural aesthetics Sealed surface if applied on façade can easily break in application	
Metals	45-100 GJ/t								
Steel	high energy cost in manufacture (but recyclable)	7850 kg/m3	1500 °C	FE + C	metalic glint: when polished can reflect light, like mirrors Prescence of carbon in steel increse hardness and mechnical strenght, while its weakens their structure	Mediocre *protecten when added Chroium*	amongst hardest materials Resiliend, but the colder, the more brittle Perfectly elastic up to certain point (elastic limit) Plasticity prevents breaking after elastic limit Ductility dependent on type of metail, most very ductile Isotropic		magnetic
Aluminium		2700 kg/m3	660 °C	Al		very tollerant		Lightweight, grreat aesthetic variety, can be reflector	non-magenetic
Copper		8800-9250 kg/m3	1083 °C	Cu		most vulnerable		good conductor of electircity	magentic
Stone: Bricks	3 GJ/t								
Wood		dependend on wood specy defined in relative density, hardwood si 1	-	Oak	.60-0.80		constantly shrinking Viariable durability, dependend on species, treatmenst can be prevented agains insects, fungi, damp, fire Lightweight, yet extremely advanced	structual oodwok	
				cedar	0.40-0.50			outdoor furnitur	
				Fir	0.40-0.60			joinery and structural woodwork	
				Pine	0.40-0.85			lgued laminates	
Granite		3000 kg/m3		Feldspar Micas quartz	non-porous high granular structure		Resistant to wear polishes very well		

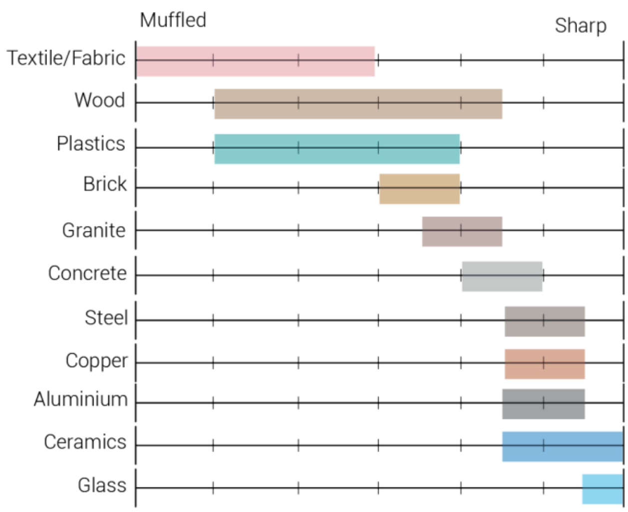
D. Sensorial experiences of materials in Amstel III

Own diagrams


Copper
non-transparant
Transparant
Matte
glossy (reflective)
Smooth
Rough
Cold
Warm
Flexible
Stiff
Muffled
Sharp
Bricks
non-transparant
Transparant
Matte
glossy (reflective)
Smooth
Rough
Cold
Warm
Flexible
Stiff
Muffled
Sharp
Granite
non-transparant
Transparant
Matte
glossy (reflective)
Smooth
Rough
Cold
Warm
Flexible
Stiff
Muffled
Sharp
Wood
non-transparant
Transparant
Matte
glossy (reflective)
Smooth
Rough
Cold
Warm
Flexible
Stiff
Muffled
Sharp
Plastics
non-transparant
Transparant
Matte
glossy (reflective)
Smooth
Rough
Cold
Warm
Flexible
Stiff
Muffled
Sharp
Textiles, fabric
non-transparant
Transparant
Matte
glossy (reflective)
Smooth
Rough
Cold
Warm
Flexible
Stiff
Muffled
Sharp


Cold
Warm
Copper
Aluminium
Steel
Glass
Granite
Ceramics
Concrete
Brick
Wood
Plastics
Textile/Fabric

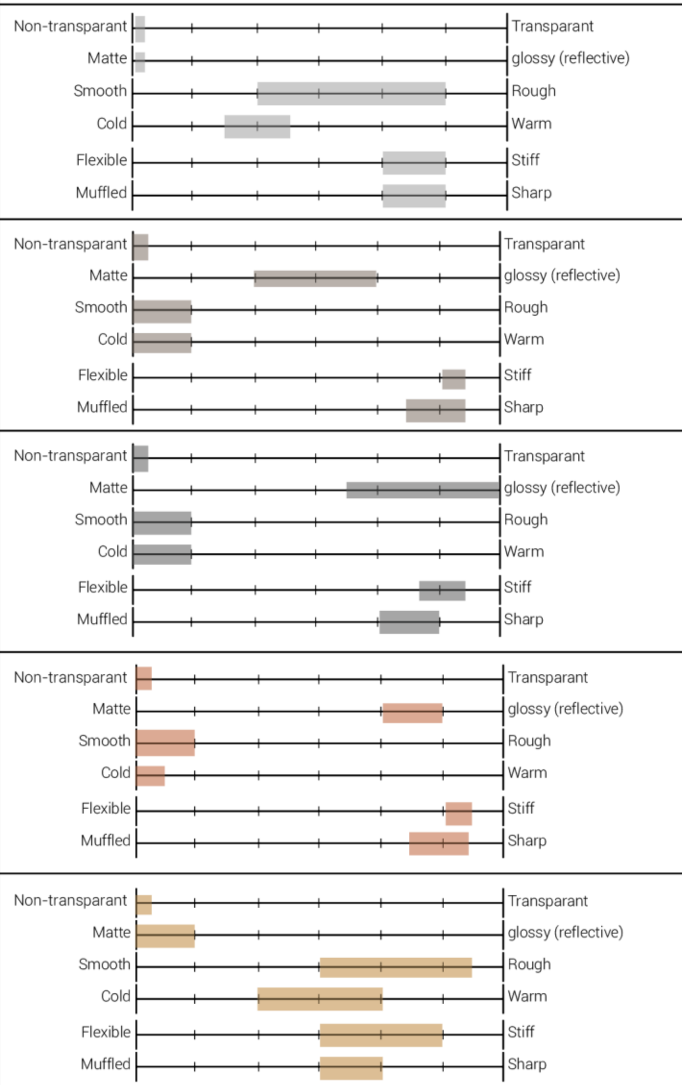

Flexible
Stiff
Textile/Fabric
Plastics
Wood
Brick
Concrete
Granite
Aluminium
Copper
Steel
Glass
Ceramics


Muffled
Sharp
Textile/Fabric
Wood
Plastics
Brick
Granite
Concrete
Steel
Copper
Aluminium
Ceramics
Glass

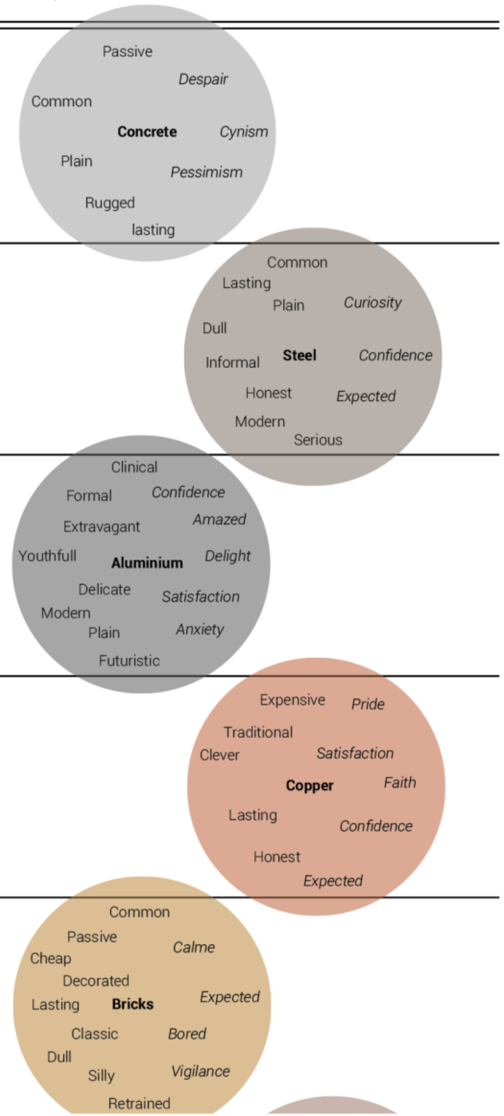
E. Toolbox for materials experience

	Applications
Concrete	Crushed into parts for aggregate Casted concrete reuse in bloks or structure Casted conrete elements when dry connected
Steel	Recycled by melting; back in the process loop Reuse of whole construction Reuse of beams, disassembled by dry joints Reuse of beams, by cut off joints
Aluminium	Melted again to make new components sheets can be bended, cutted, joint into new needs
Copper	Melted again to make new components Components cleaned and reused, in electricity and plumbing
Brick	Dependen on the easy individual bricks canbe seperated and cleaned Make new bricks out of crushed old bricks, including cement Cut into 'sheets' of masonry work

Experience | Sensorial



Experience | overall



Granite	Reused in the sheet it was applied
Wood	Reuse solid wood, if well maintained Cutted into new solid pieces and reuse Cutted into small pieces for chipboard/Osb/MDF Soil for the Earth (if not threathened)
Glass	Remelting single-glazed windows Cutted into smalle pieces Thoughened or safetyglass, only in full size reused
Ceramics	crushed ceramics as aggrregates for concrete
Plastics	crushed ceramics as aggrregates for concrete Melted and used for new plastics (dependable on type of plastic)
Textile/Fabric	New fabrics made of (partly) old fabrics Good (sound) insulation properties