European Waste Manual for Above Ground Construction

Volume I

funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002)
Project « WAMBUCO - European Waste Manual for Above Ground Construction »;
Contract N°: EVK4-CT- 2002-30006
PROJECT N°: xxxx-70003

Editing:
TU-Dresden
Umbra
Ceifa
Tec Minho
IAT
CAFOC
Raadvad

Contractors:
Consulting & Construction Logistics GmbH
Otto-Rüdiger Schulze Holz- und Baustoffrecycling
Betziner Bauholzentsorgung und Weiterverarbeitung
JOCOLAR
TEMUNDO
Duarte & Filhos, S.A.
Semural
CONSUR
Brandys OG Sön A.S.
Nordahl & Axelsen 2000 APS
SA Groupe 1000

Compilation and final Editing:
Klaus Lipsmeier, Marko Günther,
Institute for Waste Management and Contaminated Sites Treatment of Dresden University of Technology

Content

1 Introduction

The construction sector beside power production is one of the economy branches with the highest waste generation in Europe. The annual amount of waste generated by building construction in the European Union reaches approximately 100 million tons. About 80 % of all construction services are provided from small- and medium-sized enterprises (SMEs). The disposal of the generated waste is thereby undertaken without a central co-ordination by the individual companies themselves. The repeated removal of mostly mixed construction and demolition (C&D) debris from the construction sites in rather small amounts leads to high disposal costs and significant emissions from transportation processes. Being carried out by the construction workers, these processes due to their time consuming nature also have a minimising effect on productivity. The current construction practice can be altered by the introduction of an efficient, cost optimised and low-waste C&D waste management and the implementation of waste preventing measures at the construction sites, however.

Given the lack of knowledge about specific waste arising and waste-related parameters and ready-to-use planning documents such measures are difficult to implement at the construction sites at the moment. Complex intertwining within the construction industry and lacking communication between the involved actors, building owner, architects, project managers, prime contractors, service providers and disposal companies further complicates the prevention of construction waste.

With the objective to change this situation the research project "WAMBUCO" has been launched in the year 2002. The result of this undertaking is presented in form of the first European Waste Manual for Building Construction which aims at providing all actors a readily applicable instrument to examine the planned construction activities towards their relevance for waste generation and other waste management-related aspects.

The European Waste Manual for Building Construction is primarily targeted at:

- Building owners
- Project managers
- Construction enterprises
- Architects
- Disposal firms
- Producers and retailers of construction materials.

The Waste Manual consist of three Volumes:

- Volume I – providing a summary of Volume II and Volume III;

- Volume II – with the results of the empirical research of WAMBUCO for different building types and several constructions;

- Volume III – with further results of investigations including individual experiences of participants within the project.

In the Volume I two types of card files from different points of view are presented: construction specific and building specific card files.

Within the frame of the research project, the smallest functional units of a construction such as walls, ceilings, floors, storefronts, housetops and paneling have been investigated in a quantitative and qualitative way and analysed in terms of their waste management relevance. The results of these investigations have been compiled in construction card files.

Aside from the standard constructions three types of buildings: dwelling house, hotel and office buildings were analysed from the waste management perspective. The specific waste parameters for this part of the investigation are contained in building card files.

The elaborated card files are very practice-oriented. They provide the practitioners an easy-to-comprehend calculation instrument for the waste generation at the construction site. The constructions and buildings investigated as well as a short description on the application of waste codes is presented in Volume II.

Volume III presents the further results of the investigations including individual experiences of the project participants and the national situation in the participating countries, which are both interesting and relevant from the waste management perspective.

The Volume III includes the following chapters:

- Waste Management Guideline for the building practice with recommendations concerning the selection of low waste and cost optimised disposal strategies at the construction site;

- Country specific studies including a summary on the present state of waste management at the building sites in Europe;

- Training Concept with recommendations towards the implementation of the handbook’s content within vocational (training) education;

- Best-Practice card files offering innovative solutions for the prevention and utilisation of construction wastes;

- Reconstruction with important information about restoration and repair work.

The Waste Management Guideline and analysis of Country specific studies - disseminated via the Manual - do show all parties involved in building projects as well as the environmental institutions how a building project can be planned, tendered and realised using a low-waste, recycling oriented approach within a framework of increasing productivity. Best-Practice projects from the five participating EU countries were selected to illustrate that the utilised concepts refer to practice-oriented research results. The training concept elaborated within the experimental programmes of the research project is particularly future-oriented. Nowadays, building industry is confronted not only with an increase of the costs for building material and waste disposal but also with ever more stringent requirements regarding environmental protection. Only building enterprises with a low-waste and cost orientation will be competitive in the future market. That is why it is necessary to support the process of awareness raising for environmentally benign construction processes among the construction workers of tomorrow at the European level.

The Waste Manual can be used for basic teaching but also within the frame of upgrading or further qualification. By applying the positive results, which are being highlighted from the Waste Manual, construction enterprises can be taught in the sparing use of construction material and prevention of waste. The investigations concerning the completion and refinement of the Training Concept have already started within the frame of the follow-up project “Waste-Tool”.

The European Waste Manual for Building Construction which is presented here does facilitate the optimisation of the C&D waste management at construction sites, and the exploitation of the existing potentials for waste prevention during the planning and construction process, respectively.

The European approach that has been applied shall contribute to achieve a high standard in terms of environmental protection and sparing utilisation of the available resources in Europe.

2 Methodology

2.1 Overview

The 1st European Waste Manual for Building Construction, which is presented here, is the result of a two years investigation within the frame of the research co-operation WAMBUCO (Waste Manual for Building Construction).

The investigation has been carried out on three different levels (Fig. 1):

1. Country-specific studies

2. Empirical research

3. Analysis and elaboration of the Waste Manual.

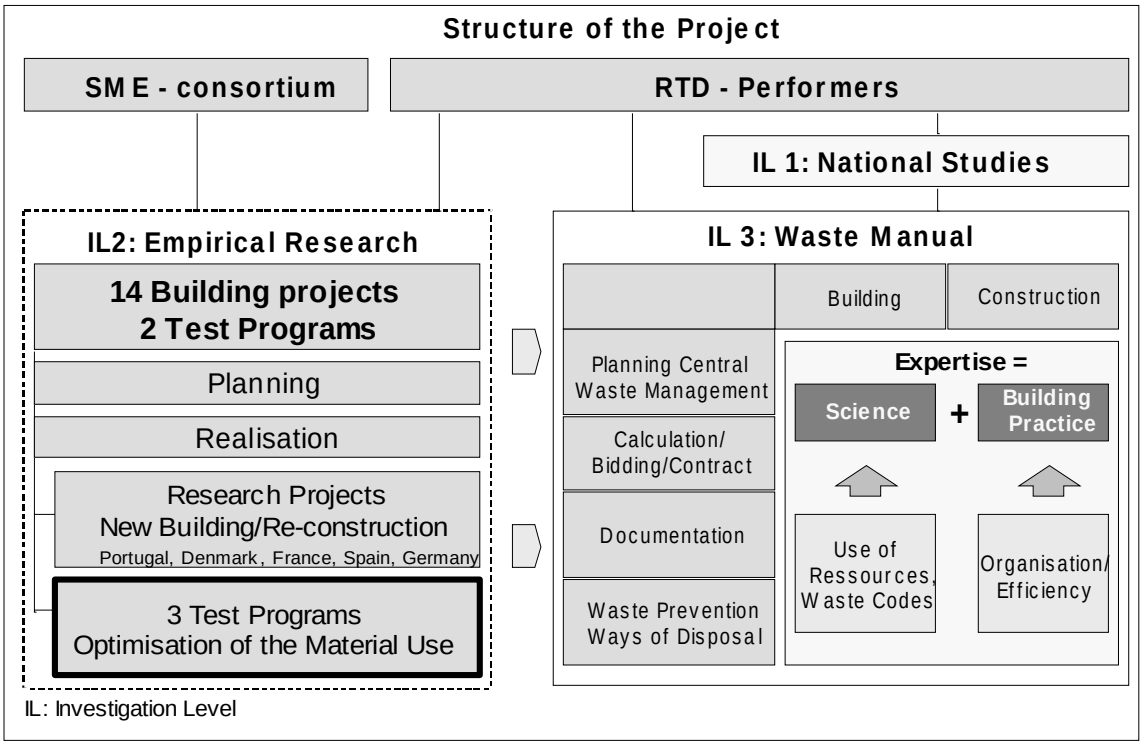


Fig. 1: Project structure and differentiation of the three investigation levels (IL)

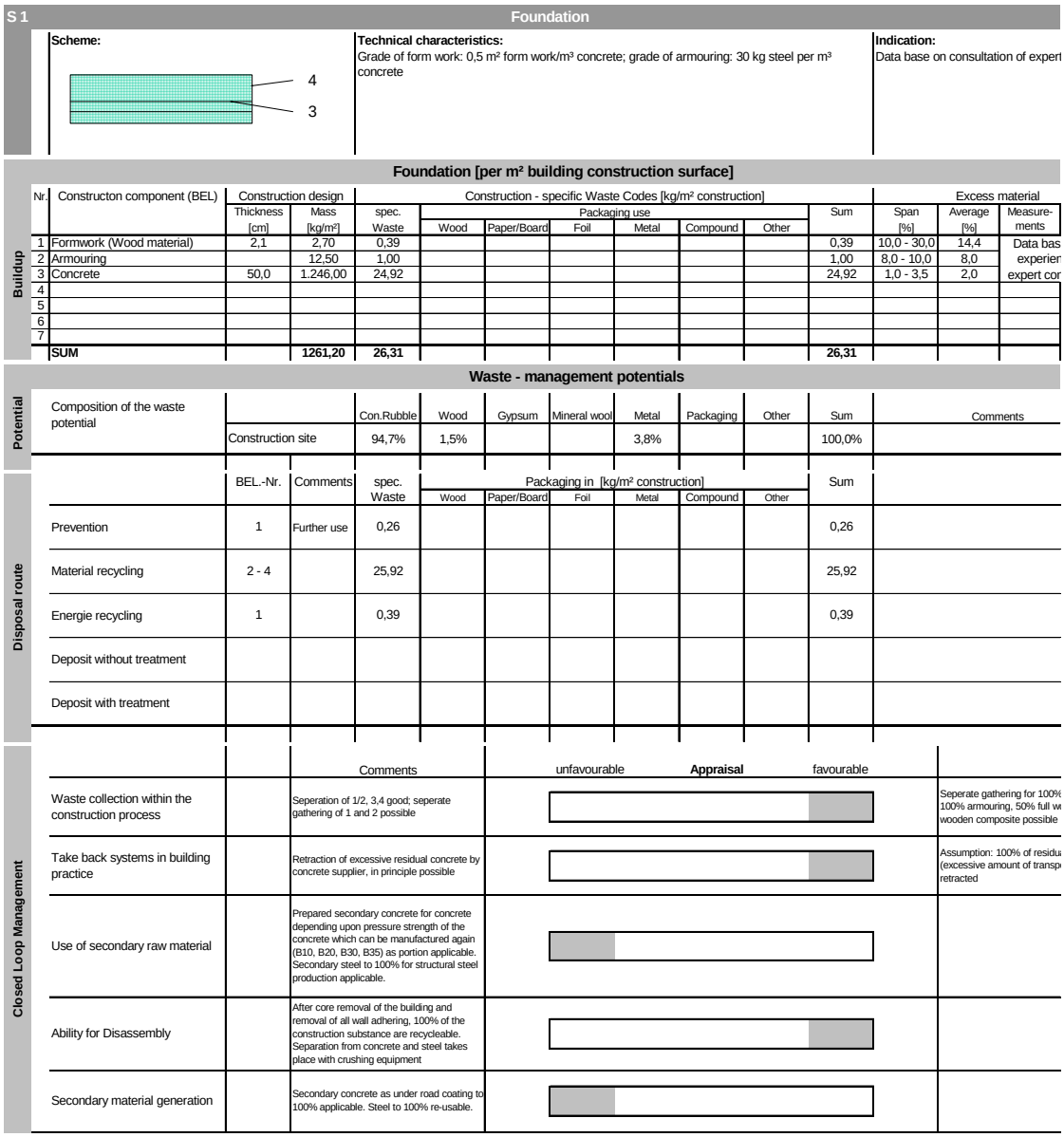
A qualitative assessment of the current status of waste disposal organisation for construction sites within the European Union has been carried out in the frame of country-specific studies on the first investigation level (IL 1 in Fig. 1).

These approaches were then investigated on the example of 14 pilot sites for construction research and by means of 2 test programmes under the real conditions of the construction practice as second investigation level (IL 2 in Fig. 1). In context with newly erected building constructions, appropriate management concepts for construction waste were developed and waste preventing approaches tested on an experimental scale. As part of this effort, construction-specific waste codes have been established simultaneously.

The third investigation level (IL 3 in Fig. 1) comprised the waste management-related analysis of both, results of the country-specific studies and empirical investigations and their consolidation, which are summed up in the first European Waste Manual for Building Construction.

2.2 Results of the investigations carried out within the WAMBUCO project

The elaborated card files (Fig. 2, Fig. 3) contain specific waste codes and data concerning the qualitative assessment of the waste potential.



S 1 — Foundation

Scheme:

Technical characteristics:
Grade of form work: 0,5 m² form work/m³ concrete; grade of armouring: 30 kg steel per m³ concrete

Indication:
Data base on consultation of expert

Foundation [per m² building construction surface]

Buildup

Nr.	Constructon component (BEL)	Construction design		Construction - specific Waste Codes [kg/m² construction]								Excess material		
		Thickness	Mass	spec.	Packaging use						Sum	Span	Average	Measure-
		[cm]	[kg/m²]	Waste	Wood	Paper/Board	Foil	Metal	Compound	Other		[%]	[%]	ments
1	Formwork (Wood material)	2,1	2,70	0,39							0,39	10,0 - 30,0	14,4	Data bas
2	Armouring		12,50	1,00							1,00	8,0 - 10,0	8,0	experien
3	Concrete	50,0	1.246,00	24,92							24,92	1,0 - 3,5	2,0	expert cor
4														
5														
6														
7														
	SUM		**1261,20**	**26,31**							**26,31**			

Waste - management potentials

Potential

Composition of the waste potential		Con.Rubble	Wood	Gypsum	Mineral wool	Metal	Packaging	Other	Sum	Comments
	Construction site	94,7%	1,5%			3,8%			100,0%	

Disposal route

	BEL.-Nr.	Comments	spec.	Packaging in [kg/m² construction]						Sum	
			Waste	Wood	Paper/Board	Foil	Metal	Compound	Other		
Prevention	1	Further use	0,26							0,26	
Material recycling	2 - 4		25,92							25,92	
Energie recycling	1		0,39							0,39	
Deposit without treatment											
Deposit with treatment											

Closed Loop Management

		Comments	unfavourable — **Appraisal** — favourable	
Waste collection within the construction process		Seperation of 1/2, 3,4 good; seperate gathering of 1 and 2 possible		Seperate gathering for 100% 100% armouring, 50% full w wooden composite possible
Take back systems in building practice		Retraction of excessive residual concrete by concrete supplier, in principle possible		Assumption: 100% of residu (excessive amount of transp retracted
Use of secondary raw material		Prepared secondary concrete for concrete depending upon pressure strength of the concrete which can be manufactured again (B10, B20, B30, B35) as portion applicable. Secondary steel to 100% for structural steel production applicable.		
Ability for Disassembly		After core removal of the building and removal of all wall adhering, 100% of the construction substance are recycleable. Separation from concrete and steel takes place with crushing equipment		
Secondary material generation		Secondary concrete as under road coating to 100% applicable. Steel to 100% re-usable.		

Fig. 2: Example of construction specific card files

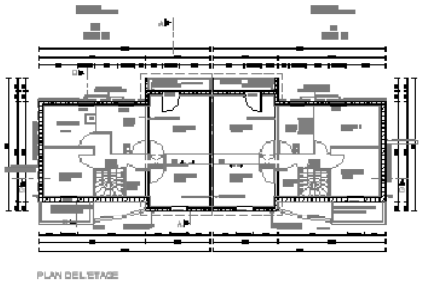
Specific waste codes for both constructions and buildings were derived on the basis of the waste amounts recorded during pilot studies and construction projects. The waste amounts were obtained as absolute figures, which do not form a comparable basis for conclusions on the waste potential of a certain construction work, however. For that reason, reference values had to be determined to which the absolute figures could be set in relation. In the present case the standard area was used as the reference value. For building constructions the standard area is 1 m² of the gross floor area.

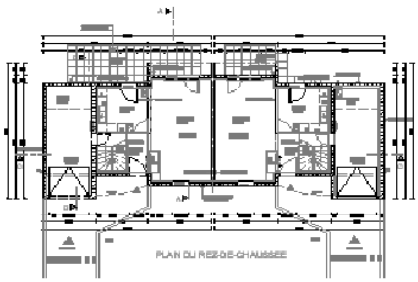
As for the investigated building types, mass- and volume related waste codes could be established. The volume-related figures had been converted into mass-specific parameters by means of the established bulk density. Furthermore established were the average disposal costs for each fraction. The mass-, volume- and cost related waste codes can be used to assess the waste related potential of the standard buildings.

Gross volumn in m³:	300,08
Gross floor area in m²:	150,04
Number of floors:	2
Duration of construction:	21 weeks
Construction costs in €:	191.176,00

Garden construction in Montbeliard

Plan





Construction	Type and Size	Planned performance	Main type of waste								Used packaging
		unit	wood	c*	metal	Inert	mixed	hazard.	foil	other	
Masonry	**concrete**	m³	x		x	x					**palets**
Woodframes	**wood**	m²	x		x						**palets**
Cover works	**cover zinc**	m²	x		x			x	x		
Sealing	**sealing**	m²	x					x	x		
Exterior wood finishing	**windows**	U	x					x			
Interior wood finishing	**doors**	U	x					x			
Partition Doublings	**plaster board**	m²	x	x	x			x			**plaster**
Tiling	**tiling**	m²	x	x		x		x			
Stuck ground	**stuck ground**	m²		x				x			
Painting	**painting**	m²		x	x			x			
Iron work, Doors of garages	**doors of Garages**	U			x			x			
Heating	**radiators**	U		x	x			x	x		
VMC	**pipe steel**	m		x	x			x	x		
Plumbing	**pipe coppers**	m		x							
Electricity	**electric cable**	m		x	x		x	x	x		
Coating frontages	**coating**	m²	x	x	x	x	x	x			**paper**
Parks	**bituminous mix**	m²	x			x		x			

c* : Cardboard and paper

Mixed waste : wood, plastics, packings, concrete packings
Concrete packings : this concrete is used for tiling

Waste	Amount in m³	Amount in t
Type		
Wood	**0,30**	
Packings (foil)	**0,40**	
Metals	**0,15**	
Mineral waste	**1,65**	3,50
Mixed waste content	**5,20**	3,00
Paper and cardboard	**1,75**	0,10
Hazardous waste	**0,50**	0,05
Plastics	**3,30**	
Concrete packings	**1,00**	
plaster	**0,10**	
Sum	**9,10**	6,65

Fig. 3: Example of building specific card files

The applicability of the waste codes for estimating the waste amounts at a construction site is illustrated in the following chapter on the example of a dwelling house.

The card files offer a tool in support of decisions concerning the selection of a cost optimised and low waste disposal strategy.

The waste potential of a construction in qualitative terms was analysed in relation to:

- Avoidance and utilisation of construction waste (CW) and packaging materials
- Treatment and depositing of construction waste and packaging materials

- Collection of construction waste and packaging materials during the construction processes
- Take-back systems applying to the construction practice
- Utilisation as secondary raw material.

Details on the qualitative waste potential of buildings concern in particular the waste composition and bulk density of the individual waste fractions. The main focus lies here on the assessment of the management of the waste at the construction site with regard to:

- Organisation of waste disposal at the construction site
- Costs of the waste disposal (prices for waste disposal, costs for the transportation of the individual waste fractions).

To have the specific waste codes established, 44 building constructions and 3 types of buildings have been investigated and analysed from a waste management perspective all together. The chosen building constructions and building types stand representatively for the developments in this sector in Europe to date.

3 Application

3.1 Introduction

The waste codes for buildings and constructions from card files can be applied to calculate the waste generation for any new building. To illustrate how the calculations are carried out, an example for a dwelling house is shown hereafter. The basic measurements for a house are shown in Tab. 1.

Tab. 1: Basic measurements of a dwelling house

Gross floor area in m²	244
Number of floors	3

Fig. 4: The dwelling house used for the example

3.2 Calculation of the waste generation for a dwelling house on the basis of construction specific waste codes

The waste codes for constructions make it possible to calculate the amount of waste that is generated during the construction process of a new building of the specified type. The calculation can be carried out with the help of a MS-Excel-based easy-to-handle software-tool, called WAMBUCALC (Fig. 5).

The kind and extent of the separate constructions in general are known before the construction process enters into its implementation phase. The characteristics of the constructions are the basis for estimating the waste amounts at the construction site. The yellow cells in the calculation sheet have to be filled with the respective parameters referring to type and area of the construction (Fig. 5). All figures have to be converted into the units specified for this.

Once the parameters have been introduced, the results are presented in the columns “Sum” and “Rate”. The data shown in these columns are calculated on the basis of waste codes from construction card files. The column “Construction component” includes all constructions, which were analysed and investigated from a waste management perspective. The details and waste parameters for these constructions are contained in the construction specific card files in Vol. 2. In the column “Sum” the total amount of waste generated during the specified construction is displayed. The column „Rate” shows the percentage contribution of the specified construction on the overall waste generation. The data in the column “Sum” can be differentiated into 7 separate fractions (s. Vol. 2) if necessary. The total waste quantity generated during the construction process of the dwelling house used in the example, is about 12,605 kg (s. Fig. 5) for a gross floor area of 244 m².

Cat.	Nr.	Construction component (BEL)	Construction design		SUM	Rate
			Unit	Amount	[kg]	[%]
Shell						
S	1	Foundation	m²	81,97	2156,63	17,1
S	2	Reinforced concrete wall in local concrete building method (20 cm)	m²			
S	3	Reinforced concrete wall in prefabricated building method (20 cm)	m²			
S	4	Reinforced concrete wall in local concrete building method (30 cm)	m²			
S	5	6,5 cm Bricklayer wall	m²			
S	6	10 cm Bricklayer wall	m²			
S	7	11 cm Brick intersection wall	m²			
S	8	12,5 cm Bricklayer wall	m²			
S	9	22 cm Brick masonry wall	m²	179,60	1033,52	8,2
S	10	30 cm Brick masonry wall	m²	328,21	3641,36	28,9
S	11	12 cm Ceiling on re-enforced concrete	m²	162,03	1711,04	13,6
S	12	20 cm Ceiling on re-enforced concrete	m²			
S	13	Valley beam Roof	m²	170,00	928,71	7,4
		SUM			**9471,25**	**75,1**
Completion work						
C	1	Facade stonework, 1-layer	m²			
C	2	Exterior drywall wall, one side plasterboard, 2-layer	m²			
C	3	Guidon wall, bilateral-two-part skin, 2-layer (industry building)	m²			
C	4	2-layer Sealing (industry building)	m²			
C	5	Dry wall, bilateral-two-part skin,2-layer	m²			
C	6	Dry wall, bilateral-two-part skin, 3-layer	m²			
C	7	Drywall wall, two sides plasterboard, 4-layer, metalic support, mineral wool insulation	m²			
C	8	Dry construction ceiling, 1-layer	m²			
C	9	2,5 cm Plaster work	m²	842,99	483,29	3,8
C	10	Compound stone floor	m²	191,00	1816,41	14,4
C	11	1-layer Painting	m²	513,50	31,27	0,2
C	12	1-layer Spray painting	m²			
C	13	2-layer Painting	m²			
C	14	2-layer Spray painting	m²			
C	15	Wall tiles, 1-layer	m²	53,49	123,45	1,0
C	16	Floor tiles, 1-layer (marble)	m²			
C	17	Floor tiles, 1-layer (ceramic 33 x 33 x 0,8)	m²	99,33	88,01	0,7
C	18	Floor tiles, 1-layer (ceramic 40 x 40 x 0,8)	m²			
C	19	Floor tiles, 1-layer (granite 40 x 40 x 1)	m²			
C	20	Granite stonework, 1-layer	m²			
C	21	Marble stonework, 1-layer	m²			
C	22	Carpet-work – tiles	m²			
C	23	Parquet-work – tiles	m²			
C	24	1-layer Sealing	m²	41,72	2,37	0,0
C	25	2-layer Sealing	m²	23,80	8,10	0,1
C	26	Roof tiles	m²	170,00	326,40	2,6
		SUM			**2879,29**	**22,8**
Technical Building Equipment						
T	1	Cold, hot and waste water and electrical power installation	m²	244,00	254,14	2,0
T	2	Elevator (three floors)	Pieces			
Refurbishment work						
R	1	Windows being repaired	Pieces			
R	2	Door being repaired	Pieces			
R	3	Roof tiles	m²			
				SUM [kg]	**12604,69**	**100,0**
				Rate [%]	**100,0**	

Fig. 5: The calculation chart for “Wambucalc”

3.3 Calculation of the waste generation for a dwelling house on the basis of building specific waste codes

If the information about the constructions used for a building is incomplete, it is possible to assess the waste generation at the construction site on the basis of specific waste codes from the building card files. The main requirement for this is a precise knowledge about the construction area of the building.

Aside from the construction area the degree of building comfort must also be known. In dependence from the complexity of the used constructions, a differentiation into three degrees of building comfort ca be made: low, medium and high.

Fig. 6 as well as the values from Tab. 3 shows on the example of a dwelling house that the degree of building comfort influences the waste amount from the construction to a large extent. They show that the waste mass increases with a rising degree of comfort.

Apart from gross floor area and degree of comfort also the relationship between building type and waste amount could be established by the research project. For this purpose three building types (dwelling house, hotel and office building) were investigated and analysed from waste management perspective. The influence building type has on the waste amount is not so apparent, however. By comparison of the two building types hotel and office building with the same gross floor area and degree of comfort, such relationship can nevertheless be seen (Tab. 2).

Tab. 2: Results of the investigations on different building types: office vs. hotel building

Building type	Gross floor area	Comfort	Length	Width	Floor-to-floor height	Number of floors	Waste mass	Waste codes
	[m²]		[m]	[m]	[m]	[-]	[t]	[kg/m² GFA]
Office building	70,000	medium	80.00	48.61	3.50	18	2375.34	33.93
Hotel building	70,000	medium	80.00	48.61	3.50	18	2355.90	33.66

In short, the waste generation at a construction site can be estimated on the basis of building specific waste codes with the knowledge on following information:

- Gross floor area
- Degree of building comfort
- Building type.

Proof for that can be provided on the example of the above described dwelling house (Fig. 2), which has a gross floor area of 244 m² and medium building comfort.

According to the figures of Tab. 3, the waste mass that must be expected from the construction process of this house is about 12.16 t.

Tab. 3: Results of the investigations for the dwelling house

Building type	Gross floor area	Comfort	Length	Width	Floor-to-floor height	Number of floors	Waste Mass	Waste Codes
	[m²]		[m]	[m]	[m]		[t]	[kg/m² GFA]
Dwelling house	240	low	12.00	6.67	2.80	3	10.94	45.58
	240	medium	12.00	6.67	2.80	3	12.16	50.67
	240	high	12.00	6.67	2.80	3	18.17	75.71

A summary of the results from the investigations on dwelling houses is presented in Fig. 6. The graphic illustrates an unequivocal relationship between the waste mass and the gross floor area. It allows finding out the expected waste quantity from the construction of a dwelling house in dependence from its gross floor area and comfort.

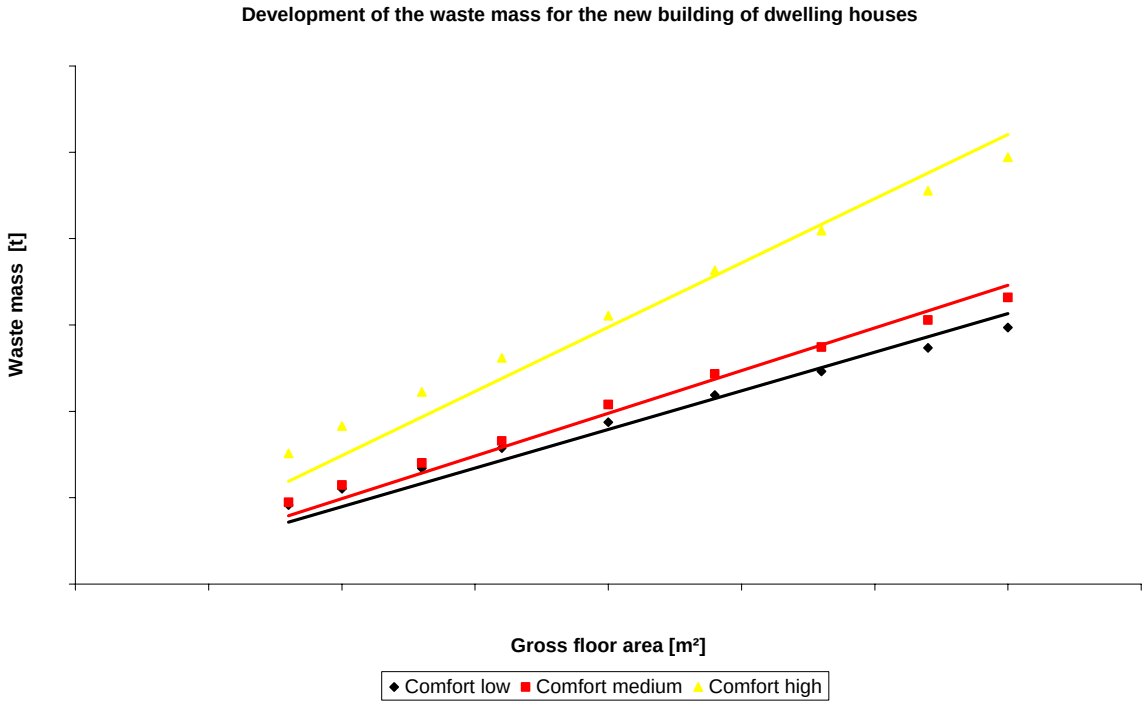


Fig.6: Development of the waste mass for the new building of dwelling houses

4 Conclusion

The results of the research project WAMBUCO, which are presented in form of the 1st European Waste Manual for Building Construction, demonstrate that the waste generation during a construction can be forecasted before the building process begins.

Such estimation can be carried out during the planning phase on the basis of building specific waste codes. The mass-, volume- and cost related waste codes can be used to assess the waste related potential of standard buildings (s. Vol. II).

The other way to assess the waste potential at the construction site is to use construction specific waste codes as the basis for calculation. The basic idea for the development of specific waste codes lies in the fact that the waste potential of a building is directly linked to the kind and extent of the constructions employed. The construction specific waste codes are contained in the so-called construction card files (s. Vol. II).

The Waste Manual contains not only the card files with the waste codes but also depicts the individual experiences made by the small and medium sized enterprises (SMEs) and other partners participating in the project. These experiences are contained in Vol. III.