DEVELOPMENT OF CONCRETE CONSTRUCTION IN EUROPE

EUROPÄISCHE ENTWICKLUNG DER BETONBAUWEISE

DEVELOPPEMENT EUROPEEN DE CONSTRUIRE EN BETON

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SUMMARY

Some aspects of the European development in concrete construction are highlighted. First, a standardization of concrete as a material in EN 206 is emphasised as a milestone. It took 25 years to finish such a standard covering all types of concrete, strength classes and durability classes. A great focus was laid on the durability in the sense of exposure classes. These are compared with a resistance in the same way as structural design is performed. Some developments are shown such as self-compacting concrete, ultra-high performance concrete and textile reinforced concrete. Finally, the environmental consciousness which has a long tradition in Europe is exemplified with blended cements and co-combustion for flyash production. The results are encouraging.

ZUSAMMENFASSUNG

Einige Gesichtspunkte der europäischen Entwicklung im Betonbau werden beleuchtet. Erst wird die europäische Norm EN 206 als Werkstoffnorm für Beton behandelt, die als Meilenstein gilt. Es dauerte 25 Jahre, eine solche Norm zu verabschieden, die alle Arten von Betonfestigkeitsklassen und Dauerhaftigkeitsklassen beinhaltet. Ein Schwerpunkt wurde auf die Dauerhaftigkeit im Sinne von Expositionsklassen gelegt. Diese werden mit dem Widerstand in gleicher Art und Weise verglichen, wie es bei der Festigkeitsbemessung gemacht wird. Einige Entwicklungen werden gezeigt, z. B. der selbstverdichtende Beton, der Ultrachhochleistungsbeton und der textilbewehrte Beton. Zum

Schluss wird der Nachhaltigkeitsgedanke, der eine lange Tradition in Europa hat, beispielhaft dargestellt an Kompositzementen und Mitverbrennungsstoffen zur Erzeugung von Flugasche. Die Ergebnisse sind vielversprechend.

RESUMÉ

Quelques aspects du developpement Européen de construire en béton sont examinés. D´abord, la normalisation du béton comme matériau en EN 206 est soulignée comme une étape importante. Il a demandé 25 ans pour finir cette norme qui contient tout les types de béton, les classes de résistance et les classes de durabilité. La durabilité a reçu grande attention avec definir les classes d´exposition. Elles sont comparées avec la resistance en la même manier que la resistance mecanique est calculée. Quelques developpements sont illustrés tell que le béton autocompactant, le béton à trés haute performance et le béton renforcé avec des textiles. Finalement, le respect de l´environnement qui a une longe tradition en Europe est illustré avec des ciments composites et la co-combustion pour la fabrication des cendres volantes. Les résultats sont encourageants.

INTRODUCTION

Europe has an old tradition in concrete construction. The first attempts go back to the 40´s of the Nineteenth Century when Joseph Monier made his flower pots of a kind of ferrocement. Joseph Louis Lambot built small ships, one of them still being available.

Fig. 1. Lambot´s ship of 1848 made of concrete [1]

They started with ferrocement which was and is still a very versatile material which can be shaped by hand. Since then, reinforced concrete developed steadily and in the early Twentieth Century prestressed concrete was developed. It is well known that concrete is the most popular construction material which is used everywhere. The total consumption in Europe per year amounts to 800 mill. tons.

Europe is growing together. This is also true for the technical goals. The European law enforces everybody not to build barriers to trade. It took more than 20 years to finalize a European Standard on concrete. The EN 206 part 1 is now ready and is introduced in all European countries. On the other hand, there is a continuous development of concrete construction. Three types of concrete are being developed and used more frequently, i.e. self-compacting concrete (SCC), ultra-high performance concrete (UHPC) and textile reinforced concrete (TRC).

In Europe there is a strong environmental movement. This means that the industry in Europe tries to reduce the impact on the environment. This is achieved through various channels. A few examples are recycling of concrete, co-combustion of coal in power plants, re-use of fresh concrete and waiste water. Sustainability of concrete construction is an important aspect and has a rather long tradition. All these aspects will get due attention in the following.

STANDARDIZATION

The new standard EN 206-1 [2] deals with the specification, performance, production and conformity. It is the materials standard which is needed in conjunction with the Eurocode. The Eurocode is the design code of concrete structures. EN 206-1 deals with the specification of the material. There the concrete classes are specified as strength, workability and density is concerned. The code is valid for all types of concrete, i.e. normal weight concrete, lightweight concrete and heavy weight concrete. The density classes are lightweight between 800 and 2000 kg/m^3, normal weight between 2000 and 2600 kg/m^3 and heavy weight more than 2600 kg/m^3. The strength classes range from C8/10 until C 100/115 and for lightweight from LC 8/9 until LC 80/88. The whole range of normal strength and high strength concrete is covered. Concrete is specified in three categories: there is a *standard concrete* for low strength until C 16/20 with rather fixed composition. The next one is designed concrete which is the most used. There, the properties are specified such as strength, workability and others.

There is a third category which is called the prescribed concrete. There, the composition is prescribed and the concrete producer mixes the concrete according to the specifications which are received from the specifier.

There are several rules for the conformity of the concrete. The rules are given in detail for the concrete manufacturer and also for the concrete consumer. All requirements are based on statistics, the so-called characteristic strength depends on a 5% quantile of the normal distribution. A new aspect of the conformity control is the concrete family. A family consists of similar concrete mixes, i.e. they should be of the same type of cement, aggregates from the same geological origin, not more than five strength classes. Also lightweight aggregate concrete may fall into a concrete family. The aim of this procedure is to reduce the number of specimens which are necessary for the conformity control of concrete.

Together with the EN 206 there is also a standard for the execution of concrete works (EN 13670). There is an important chapter on the curing of concrete. Curing measures depend on the type of cement, the temperature and the environment during hardening of the concrete.

Table 1. Minimum curing time of concrete in exposure classes according to EN 206-1 except X0 and XC1

Surface temperature T [°C]		Minimum curing time [days]			
		Strength development of concrete			
		$r \geq 0.50$	$r \geq 0.30$	$r \geq 0.15$	$r < 0.15$
1	$T \geq 25$	1	2	2	3
2	$25 > T \geq 15$	1	2	4	5
3	$15 > T \geq 10$	2	4	7	10
4	$10 > T \geq 5$	3	6	10	15

It can be seen that the duration of curing is rather long if there is a low temperature and if a slow cement is used. On the other hand, at higher temperature and in the case of a fast cement the curing time is rather short.

There are three classes of supervision. The first class with the lowest requirements are valid for strength classes ≤ C25/30. The next higher supervision class is applicable for C 30/37 to C 50/60. The highest supervision class is reserved for high strength concrete ≥ C55/67. Before the new standards were made there were national guidelines for high strength concrete. These are now obsolete.

The standard contains the famous tables F2.1 and F2.2. These tables specify the composition of the concrete with respect to environmental classes. Environmental classes have been introduced for the detailed description of environment. Former standards were rather crude with respect to durability. We have now 18 durability classes ranging from X0 until XA3. The main parameter is the kind of attack of the environment. There are two main causes: the first one is the corrosion of the reinforcement. There is the aspect of carbonation of concrete and second is the ingress of chlorides. Chlorides either stem from the deicing salts or from seawater. Then, there is the corrosion of concrete due to frost action and frost with deicing salts. Secondly, there is aggression of chemicals in water or soil. In Germany there is a third type of aggressive environment, i.e. mechanical abrasion. The table shows the exposure classes as specified in EN 206-1 with an informative description of actions.

Table 2. Exposure classes acc. to EN 206-1

Class designation	Description of the environment	Informative examples where exposure classes may occur
1 No risk of corrosion or attack		
X0	For concrete without reinforcement or embedded metal: All exposures except where there is freeze/thaw, abrasion or chemical attack For concrete with reinforcement or embedded metal: Very dry	 Concrete inside buildings with very low air humidity
2 Corrosion induced by carbonation		

Where concrete containing reinforcement or other embedded metal is exposed to air and moisture, the exposure class shall be classified as follows: NOTE: The moisture condition relates to that in the concrete cover to reinforcement or other embedded metal but, in many cases conditions in the concrete cover can be taken as reflecting that in the surrounding environment. In these cases classification of the surrounding environment may be adequate. This may not be the case if there is a barrier between the concrete and its environment.		
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity Concrete permanently submerged in water
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact Many foundations
XC3	Moderate humidity	Concrete inside buildings with moderate or high air humidity External concrete sheltered from rain
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure class XC2
3 Corrosion induced by chlorides other than from sea water		
Where concrete containing reinforcement or other embedded metal is subject to contact with water containing chlorides, including de-icing salts, from sources other than from sea water, the exposure shall be classified as follows:		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides

XD2	Wet, rarely dry	Swimming pools Concrete exposed to industrial waters containing chlorides
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides Pavements Car park slabs
4 Corrosion induced by chlorides from sea water		
Where concrete containing reinforcement or other embedded metal is subject to contact with chlorides from sea water or air carrying salt originating from sea water, the exposure shall be classified as follows:		
XS1	Exposed t airborne salt but not in direct contact with sea water	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spray zones	Parts of marine structures
5 Freeze / thaw attack		
Where concrete is exposed to significant attack by freeze/thaw cycles whilst wet, the exposure shall be classified as follows:		
XF1	Moderate water saturation, without deicing agent	Vertical concrete surfaces exposed to rain and freezing
XF2	Moderate water saturation, with deicing agent	Vertical concrete surfaces of road structures exposed to freezing and airborne deicing agents
XF3	High water saturation, without deicing agent	Horizontal concrete surfaces exposed to rain and freezing

XF4	High water saturation, with de-icing agent or sea water	Road and bridge decks exposed to deicing agents Concrete surfaces exposed to direct spray containing deicing agents and freezing Splash zone of marine structures exposed to freezing
6 Chemical attack		
Where concrete is exposed to chemical attack which occurs in natural soils and ground water as given in table 2, the exposure shall be classified as given below. The classification of sea water depends on the geographical location; the classification valid in the place of use of the concrete applies. Note: A special study may be needed to establish the relevant exposure condition where there is: - limits outside of table 2; - other aggressive chemicals; - chemically polluted ground or water; - high water velocity in combination with the chemicals in table 2.		
XA1	Slightly aggressive chemical environment acc. to table 2	
XA2	Moderately aggressive chemical environment acc. to table 2	
XA3	Highly aggressive chemical environment acc. to table 2	

The famous tables F2.1 and F2.2 specify the composition of the concrete. However, these tables could not be agreed upon in the technical committee. The differences of climate between Southern Europe, which is subtropical, and Northern Europe, which is almost arctic, were too large. Also the national experiences with concrete compositions deem to satisfy the environmental actions.

So the tables are informative and national rules have been edited with respect to the concrete composition. As an example the German specifications are given in Table 3.

Strictly speaking, the tables are only valid for CEM I cement (Portland cement). So, in addition a rather large table has been issued with respect to the use of the other 26 cements specified in EN 197-1. Due to space constraints this table is not shown. For the Europeans it was a milestone to have one common standard in Europe.

Table 3. National specifications for the composition of concrete (DIN 1045-2)

	Concrete attack								
	Frost without/with deicing salt or seawater						Chemical attack		
Exposure class	XF1	XF2 [1)]		XF3		XF4 [1)]	XA1	XA2	XA3
max. w/c ratio	0.60	0.55	0.50	0.55	0.50	0.50	0.60	0.50	0.45
min. compressive strength class	C25/30	C25/30	C35/45	C25/30	C35/45	C30/37	C25/30	C35/45	C35/45
min. cement content, kg/m³	280	300	320	300	320	320	280	320	320
min. cement content with addition, kg/m³	270			270	270		270	270	270
min. air content, % by vol.		4.0		4.0		4.0	-	-	-
Other requirements	Aggregate with additional requirement against frost and deicing salt								
	F4	MS_{25}		F2		MS_{18}			

1) Additions may not be taken into account for the calculation of water-cement ratio and min. cement content

SELF-COMPACTING CONCRETE (SCC)

SCC is a development which started in Japan in the 80´s of the last century. However, it is forgotten that the underwater concrete which has been used in Europe long before had similar properties with similar composition. However, it was never used in normal, say dry, environment. There are specifications for SCC in various countries such as The Netherlands or Germany. For the measurement of workability we use the spread table, the funnel and the J-ring. For the design of SCC a relation has been established between the funnel time and the slump flow as Fig. 2 shows.

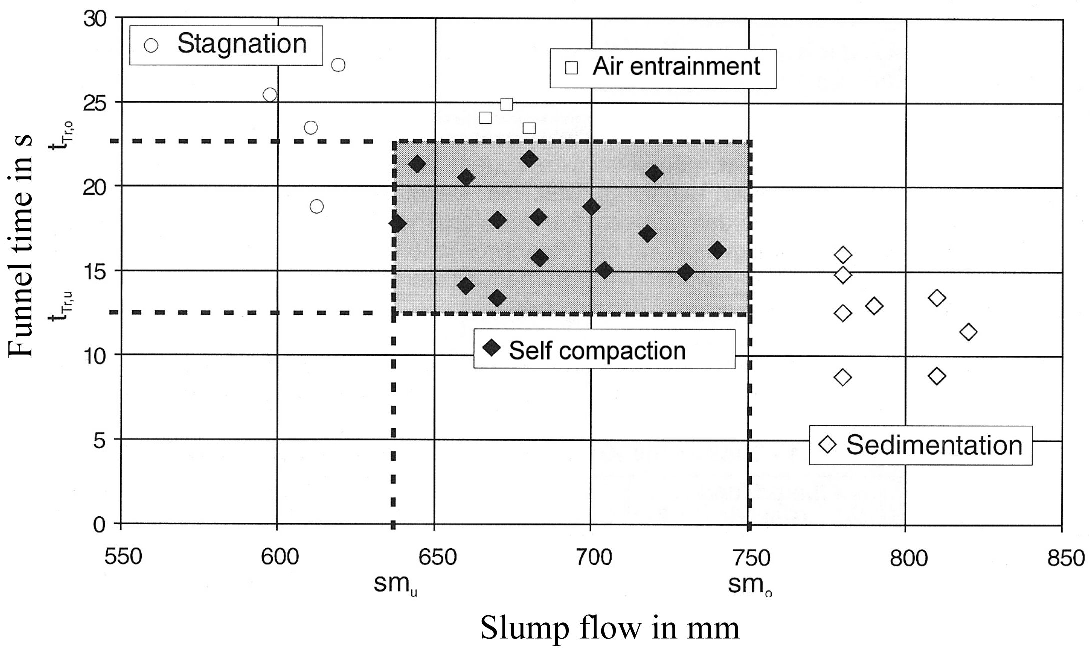

Fig. 2. „Window" for the design of SCC [3]

The figure shows the relation between the two properties. It has been demonstrated that all concretes which lie in the window in the middle of the figure, fulfill the requirements of self compacting concrete. The left hand concretes are not workable since they are blocking. The right hand concretes outside the window segregate. However, the window is not valid for all types of concretes since the composition can be adjusted to the amount of fines or the amount of stabilising agents. So, a concrete producer will always make his own window and will check the outcome of the conformity control against the window. It should be mentioned that the use of SCC is still very restricted in the European countries. An inquiry has shown that the consumption is about 15 % in Denmark, 1 % in Germany, 5 % in Sweden, 4 % in Switzerland.

The rather low consumption of SCC is due to restricted experiences with this type of concrete. The higher price, the sensitivity to composition variation and also the fact that labour cost is rather low in many European countries due to a surplus of labourers, are responsible.

ULTRA-HIGH PERFORMANCE CONCRETE (UHPC)

UHPC has started in France when the company Bouygues developed this fine grain high-strength concrete. The composition of the concrete is about the following:

RPC Premix with: 700 kg CEM, 225 kg silicafume, 990 kg sand, 210 kg quarz flour, 45 kg plasticiser, + 195 kg water + 200 kg steel fibers.

This mix with a high cement content and with very low water cement ratio, with the use of silica fume and small grain aggregates lead to strength classes of 150 MPa. Usually fibres are added in order to reduce the brittleness of the material. If heat treatment is added to normal curing then the strength can even be extended to 230 MPa. Executed examples show that rather elegant structures can be made of this material.

Meanwhile, the material spread over the whole world. Examples are available from Japan, Korea and Canada. What is still missing is the intrinsic use of this type of materials. All structures so far follow more or less the traditional design of a concrete structure. However, the material should allow for much more diversity and shapes. Since the material is fluent in the beginning and hardens in a form. One can think upon the manufacture of cast iron especially as prefabricated elements are concerned.

Fig. 3. Bridge in Quebec, Canada [4]

Fig. 4. Bridge in Korea [5]

TEXTILE REINFORCED CONCRETE (TRC)

Textile reinforced concrete is a new generation of fibre reinforced concrete. The reinforcement consists of continuous fibres which are made of polymer material. Polymers are aramid and carbon. Also the mineral material glass can be used. Table 4 shows three types of fibres which are currently being used.

Table 4. Examples of textile reinforcement [6]

Property, unit	Type		
	C	CE	AR
Material	Carbon	Carbon	AR glass
Structure of fabric	Biaxial 0°/90°	Epoxy imp. biaxial 0°/90°	Biaxial 0°/90°
Weight, g/m^2	320	135	500
Roving, tex	1700	1700	2500
Area of one roving, mm^2	0.9	0.9	0.9
Mesh size, square, mm	10	25	10
Maximum tensile force per roving, N	1100	2700	300
Tensile strength of roving, MPa	1220	3000	335

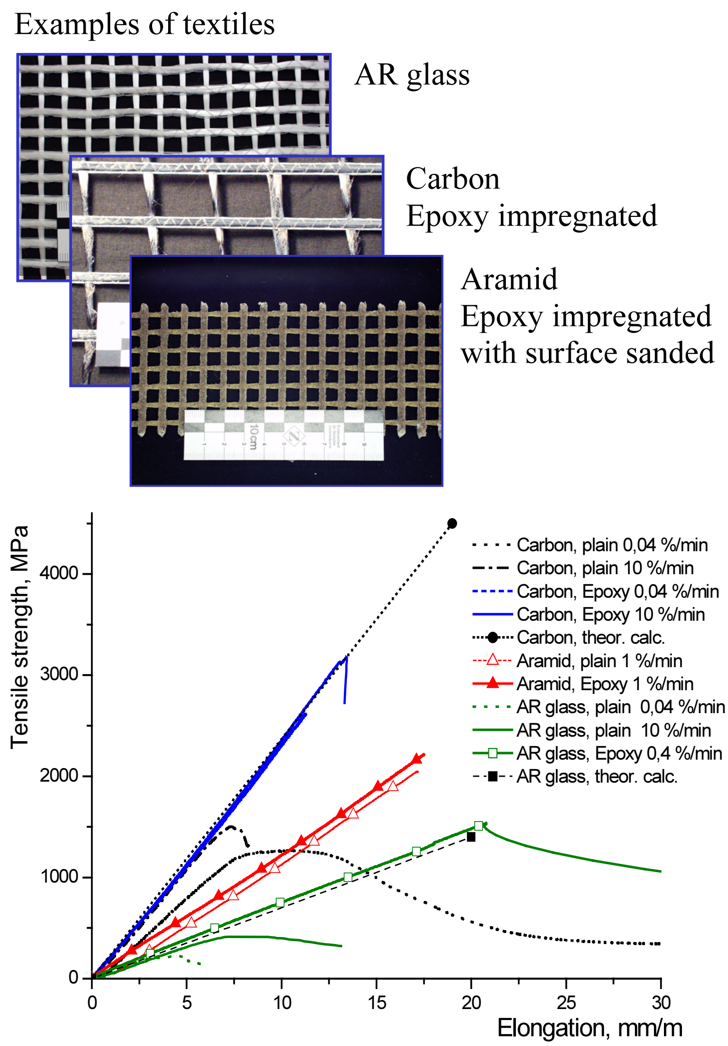

Fig. 5. „Theoretical“ and „practical“ tensile strength of different textile reinforcements [6]

The reinforcements are rovings of these materials. Rovings are composed of hundreds of filaments with a diameter of some millions. The tensile strength is very high ranging between 1500 and 3000 MPa. All these types of material are elastic almost upon fracture. Despite this elasticity and non yielding behaviour one can make ductile structural elements. Ductility is due to delamination and bond failure rather due to brittle fracture of the material. Fig. 6 shows the load deflection behaviour of strips in the bending test.

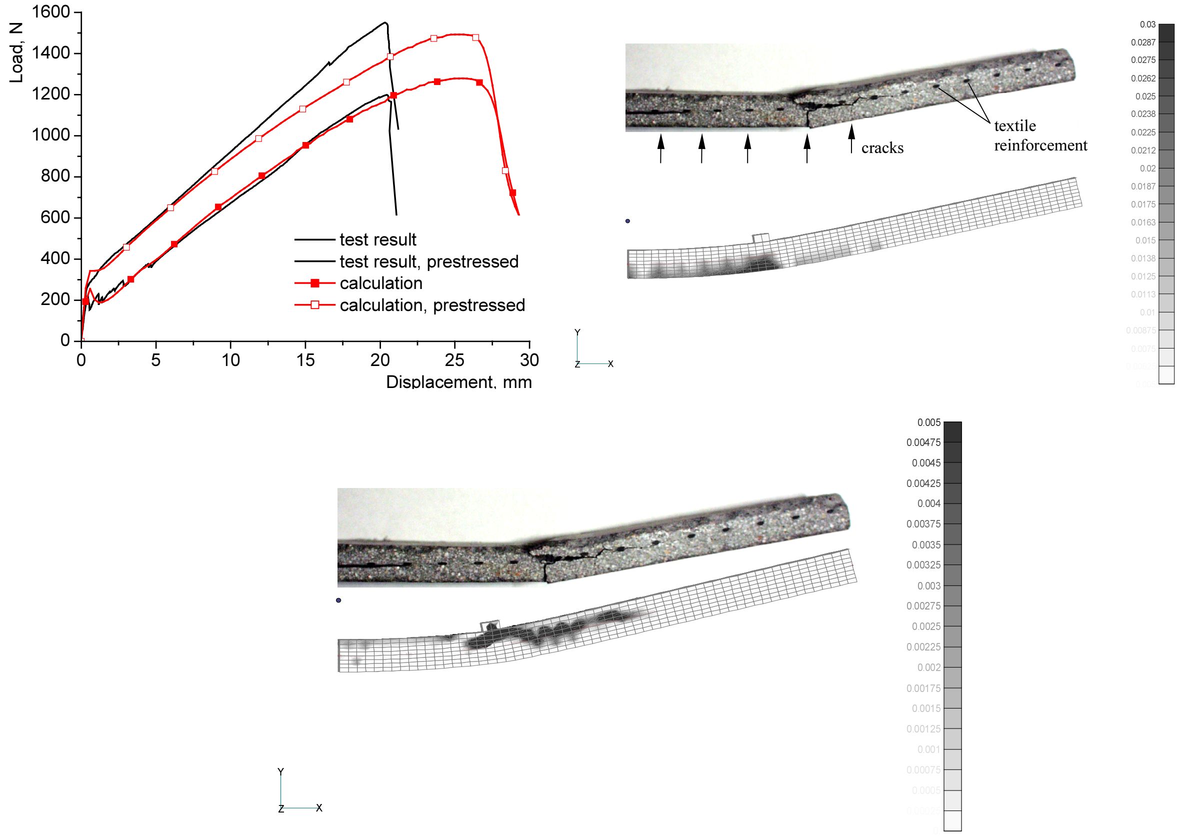

Fig. 6. Results of textile reinforced concrete [6]

Fig. 6 shows clearly the linear elastic beginning of the load deflection curve. It shows the cracking load and it shows also the deflection hardening behaviour of the material. Finally, after reaching the maximum load one gets failure but not a very brittle one but a decay of the load with increasing deflection. This behaviour can be improved if the textile is prestressed.

Due to prestressing the first elongation of the textile is eliminated which is due to the stretching of the material. All woven fabrics show a certain undulation of the filaments. When the material is prestressed this undulation is suppressed. Furtheron, we have also an increase of the load due to the fictitious increase of the tensile strength of the matrix so both facts yield an increase of the cracking load and also an increase of the strain hardening of the material.

ENVIRONMENT

There is a rather long tradition in Europe with respect to the sustainability of materials and structures. The Kyoto agreement has been signed by the European countries and this enforces the countries to reduce CO_2 emission and strive for more environmental consciousness. To reduce CO_2 emission by cement production is the use of blended cements (CO_2 production per t Portland cement is 0.93 t), the same is true for energy consumption.

Energy

The use of composite cements is spreading in Europe. Two main factors enforce the cement producing companies to make composite cements instead of pure Portland cement: first the consumption of energy and second, the use of by-products of other fabrication processes. Burning of Portland cement klinker is a very energy consuming process. Per ton of klinker one needs 3500 MJ of energy. If a part of cement can be replaced by other materials which is ready one can save a great deal of energy. This has been used for decades for the blast furnace slag cement which has a very long tradition in Europe. The first application goes back to 1872. Since that time blast furnace slag cement is used in all countries of Europe. For instance, the Netherlands use more slag cement than Portland cement which has various reasons.

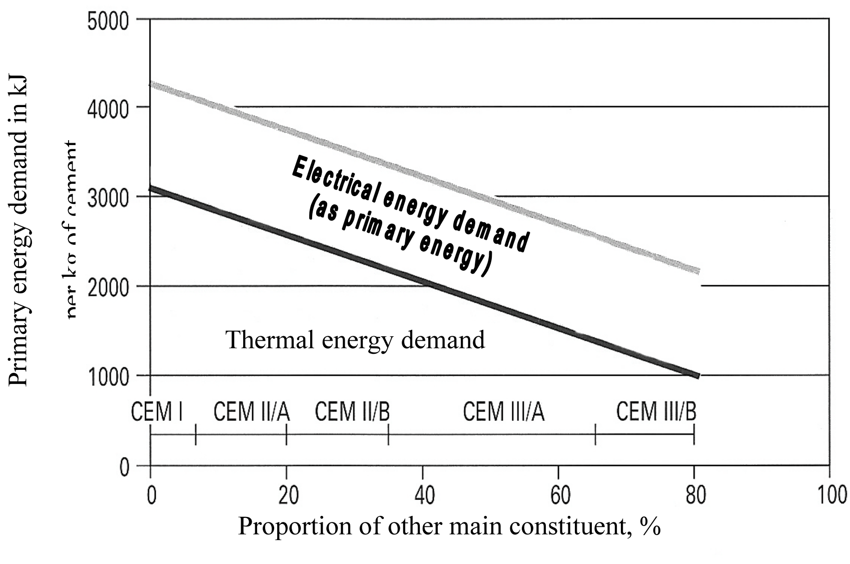

Fig. 7. Energy demand for cement production [7]

The first reason is that there is a very good slag available from the Dutch steel works in Ijmuiden. Second, it has been shown that blast furnace slag cement is superior to Portland cement in marine environment. Third, it produces less heat of hydration which makes it very suitable for thick-walled structures which are occurring in hydraulic structures very frequently. Nowadays, all other types of secondary material is used for cement production. These can be either natural products such as limestone or trass, these can be modified natural products such as phonolite, or these can be artificial products such as flyash and silica fume. These products make that the energy consumption is lower for the blended cement production than for the pure Portland cement.

Co-combustion

There is a great pressure on the ecological reuse of waste materials. One can think about the reuse of the material as such, as the replacement of other material in the building and construction process or one can think about the thermal recovery of the energy which is accumulated in the material. Looking to the materials involved, namely petcoke, sewage sludge, paper sludge, bone meal, straw, biomass and even banknotes (when the old currencies in Europe were replaced by the Euro), one realizes immediately that an ecological and economical reuse of these materials is impossible. However, a thermal recovery of the material is feasible. Power plants use it as a welcome replacement of coal.

Of course, the consequences on fly ash have to be checked with respect to the influence on the concrete like workability, air content, hydration of cement, freeze-thaw and de-icing salt resistance and maybe other properties. The aim should be to determine the limit of secondary fuel which can be used without changing the fly ash properties significantly. Some countries have carried out extensive test programs in order to establish such limits. It turned out that the limits depend on the type of material which is co-combusted, ranging between 5 and 15%. In view of the large qualities which are fired in the power plants it is a considerable amount.

The result of co-combustion results in an important ecological and, at the same time, economical profit. As long as the concrete properties do not change significantly due to this type of fly ash there are no arguments against the use of secondary fuel. The standardization organization has to make sure the limits of co-combustion.

In many countries in Europe experience with co-combustion has been gained. In a CEN report [8] there are requirements about the composition of the material used as co-combustion material in different countries as Table 5 shows. Table 6 shows the technical requirements for flyash from co-combustion according to EN 450.

Table 5. Requirements for materials allowed to be used as co-combustion material in different European countries

Country	property/parameter	-	NL [1)]	DE	Be	DK	I			
Co-combustion material		Unit		Sewage sludge	Sewage sludge	Straw	Residues from coal and coke from steel industry [3)]	Municipal waste	Sewage sludge	Paper sludge
Parameter	-	-	Require-ment							
General properties	Calorific value (LL)	kJ/kg	-	-	-	-	16000	15000	8560	1200
	Humidity (UL)	%		-	-		8/6	25	20	30
	Ash content (UL)	%			-		-	20	-	10
Element content (UL	Chloride	%		-	-		-	0.9		0.9
	Cl (organic)	mg/kg		-	-		-		1	
	Sulfur	%		-	-		2/1.5	0.6	0.6	0.5
	P_2O_5	%		25 [2)]	-		-	-	-	

Heavy metal content (UL)	Arsenic	mg/kg dry matter		-	250		-	9	9	9
	Cadmium			10	10		-			
	Chromium			900	1250		-	100	100	50
	Copper			800	375		-	-	-	300
	Copper (soluble)			-			-	300	300	-
	Mercury			8	5		-	-	-	-
	Manganese			-			-	400	400	150
	Nickel			200	250		-	40	40	20
	Lead			900	1250		-	-	-	200
	Lead (volatile)			-			-	200	200	-
	Zink				1250		-	-	-	-
	Cd+Hg			-	-		-	7	7	7
	Vanadium			-	-		-	-	-	-

[1] In the Netherlands the requirements are based on the framework of emission limits and limits of hazardous wastes and part of the permits for co-combustion. the Dutch power plants analyse the co-combustion streams and reject the policy for the choice of co-combustion materials on the quality of the byproducts.

[2] related to the ash of the sewage sludge

[3] during the technical process of steel production coal and coke is combusted; from this combustion residues occur

LL: lower limit

UL: upper limit

Table 6. Technical requirements for fly ash from co-combustion according to EN 450

Reference	EN 450
LOI % by mass	≤ 5
Cl % by mass	≤ 0.10
SO_3 % by mass	≤ 3.0
Free CaO % by mass	≤ 1.0
Fineness % by mass	≤ 40
Activity index %	≥ 75 at 28 d ≥ 85 at 91 d
Soundness mm	≤ 10

One can see that there are requirements with respect to loss of ignition, chloride, sulphate, free calciumoxide and fineness and the activity and the saltness. An extensive investigation has been made in the Netherlands.

Many co-combustion materials have been used. An ecological concern is that heavy metals and other elements can be leached from concrete which contains flyash with co-combustion material. Tests in Germany have shown that leachate from the co-combustion flyash is within the range of the concentration in the leachate obtained from coal flyash.

Comparing the results with the requirements one can state that all co-combustion materials have fulfilled the requirements when they are added as small percentage of the coal.

Tests have also been carried out on the durability of concrete. An example is the ingress of chloride. Fig. 8 shows that there are no large differences between the reference concrete and the concrete made of co-combustion flyash.

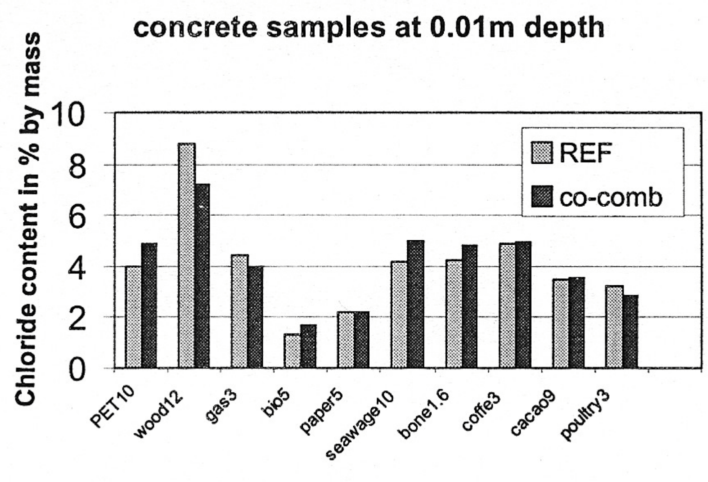

Fig. 8. Chloride penetration into concrete with flyash obtained from co-combustion of different co-combustion materials [8]

Also the freeze-thaw behaviour has been investigated. The conclusion was that there were no significant differences between concrete samples with flyashes from co-combustion and reference flyashes. Summarizing it must be noted that it is an economical and ecological advantage to use waste material as co-combustion material. If the co-combustion material is limited with respect to the coal which is incinerated one can always stay within the limits of concentration of heavy metals and other elements. In Germany work was focussed on flyash obtained from co-combustion and sewage sludge up to maximum of 5% by mass as replacement of coal. The results show that 5% had no significant influence on the EN 450 properties and the leaching behaviour of the flyash. In Germany, a co-combustion of sewage sludge up to an amount of 5% by mass is allowed. Trials have been performed with petcoke within the framework of technical approvals with petcoke contents up to 50% by mass replacement of coal. No significant influence was reported.

Recycling

Recycling of building material is encouraged in Europe. There are several guidelines available in various European countries. For example, the German DIN 1045-2 together with [9] allows 45% recycled material for exposure class X0 and XC1 to XC4, 35% for XF1 and XF3, 25% for XA1.

Table 7. Allowable percentage of recycled aggregate > 2 mm with respect to total aggregate. Type 1 aggregate contains ≥ 90% crushed concrete, type 2 ≥ 70% [9]

Arrange of application		Aggregate type 1 acc. to DIN 4226-100	Aggregate type 2 acc. to DIN 4226-100
ASR guideline	DIN EN 206-1 and DIN 1045-2		
1	2	3	4
WO (dry)	Carbonation XC1	≤ 45	≤ 35
WF [1)] (moist)	No risk of corrosion X0 Carbonation XC1 to XC4		
	Frost without de-icing salt XF1 [1)] and XF3 [1)] and in concrete with high water penetration resistance	≤ 35	≤ 25
	chemical resistance (XA1)	≤ 25	≤ 25
[1)] additional requirements see § 1, (3) and (4)			

It is also allowed to use recycled water and fresh concrete [10]. When a recycling aid is used [1] the fresh concrete can be saved for several days and reactivated together with new fresh concrete.

CONCLUSION

Concrete exists in Europe since the middle of the 19th Century. The development is continuing. The emphasis shifted from strength to durability and environmental issues. This aspect has been demonstrated at the new European standard for concrete and also some concrete examples. On the other hand, new materials evolve which have superior properties.

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[10] DAfStb-Richtlinie „Herstellung von Beton unter Verwendung von Restwasser, Restbeton und Restmörtel“, Berlin, August 1995

[11] Technical Approval Delvo Stop 10 G (RH/RB), Berlin 2000