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Tyres as an alternative fuel

The use of alternative fuels and raw material is common practice in the European cement industry. Dirk Lechtenberg gives an overview of scrap tyres as an alternative fuel in this excerpt from MVW Lechtenberg & Partner's Alternative Fuels & Raw Materials Handbook. Due to be published in the summer of 2011, the handbook will give an insight into over 80 different types of alternative fuels and raw materials with detailed descriptions of the availability, common use and practice in the cement industry. This includes processing considerations, the influence on the environment, clinker production and the economics of the various alternative fuels.

Above: 1Bnt of scrap tyres become available every year. The cement industry is one that can benefit greatly from this supply.

Scrap tyres are tyres that are no longer suitable or legal for their intended use due to damage, brittleness or low tread depth. By the time it is scrapped, a tyre generally loses around 20% of its weight. Tyres comprise natural rubber, synthetic rubber, carbon black, oil and various reinforcers.

Quantity and availability

Over 1Bn tyres are sold worldwide each year, which causes around 1Bn tyres to be scrapped. Despite an increase in the service life of tyres, volumes are growing constantly because of the increased vehicle use worldwide. The amount of tyres scrapped in various European countries in 2006 are shown in Table 1.

Right - Table 1: Number of scrap tyres from different European countries. **Source**: Kurt Rechner, Altreifen-Recycling, (www.EnTire-engineering.de)

Country	Tyres (1000t/yr)
Austria	55
Belgium / Luxembourg	82
Bulgaria	10
Croatia	15
Cyprus	5
Czech Republic	80
Denmark	45
Estonia	11
Finland	45
France	398
Germany	585
Greece	48
Hungary	46
Ireland	40
Italy	380
Latvia	9
Lithuania	9
Malta	1
Netherlands (Cars only)	47
Norway	47
Poland	146
Portugal	92
Romania	50
Slovakia	20
Slovenia	23
Spain	305
Sweden	90
Switzerland	54
UK	475
TOTAL	**3213**

Composition of tyres

Tyres have a complex composition. Depending on their size and intended use they may vary in design, construction and total weight. The weight of a used passenger tyre in Europe is about 6.5kg but that of a truck tyre is about 53kg. These values and others are presented in Table 2.

Below- Table 2: Weights of different tyre types. **Source:** BASEL Convention, 'Technical guidelines on the identification and management of used tyres,' (December 1999).

Vehicle type	Tyre weight (kg)
Passenger car	6.5 - 9.0
Light goods vehicle / van	11
Heavy goods vehicle	50
Long-haul truck	55 - 80
Agricultural vehicle	100

Chemical composition

The main component of a tyre is rubber compound and the compositions of the tyres produced by different manufacturers are very similar. Table 3 shows the material composition of tyres.

Apart from differences in design and sizes, tyres are generally homogeneous. The average chemical composition is given in Table 4.

Tyres are 100% recyclable and are a valuable resource. Many countries with environmental legislation refer in their waste management practice to tyres in the so-called waste management hierarchy. This sets the priorities of what to do with scrap tyres. In priority order these are recycle, re-use, production of crumbs and strips, depolymerisation, energy recovery and disposal.

In Germany in 1990 about 44% of used tyres were recycled, 41% were converted to energy and 15% were disposed on landfill sites or disappeared unknown [H.Vest]. Since 2005, landfilling of tyres has been outlawed in Germany.

The economic value of tyres to cement plants

In order to calculate the benefits from substitution of primary fuels the following considerations have to be taken into account.

Calorific value - To substitute 1t of coal around 0.75 - 0.91t of scrap tyres is needed. Compared to the high pet coke calorific value the substitution factor is slightly more. Around 1.01 - 1.22t of scrap tyres is needed to substitute 1t of pet coke.

Biomass / CO_2-value - Investigations show that on average 18.3% of the carbon in a passenger car tyre and 29.1% of that from truck tyre derived from biomass is natural caoutchouc. Taking this into account, the net CO_2 emission factor is reduced from the default value of 85t of CO_2/TJ (from IPCC) to approximately 59t of CO_2/TJ for passenger car tyres and 43t of CO_2/TJ for truck tyres, (from C Clauzade).

Material	Passenger car	Truck
Rubber / elastomers	47%	45%
Carbon black*	21.5%	22%
Metal	16.5%	25%
Textile	5.5%	0%
Zinc oxide	1%	2%
Sulphur	1%	1%
Additives	7.5%	5%
*Part of carbon black may be replaced by silica in certain types of tyres		

Far left - Table 3: Typical material composition of passenger car and truck tyres. **Source:** BASEL Convention - Technical guidelines on the identification and management of used tyres. (December **1999**).

Element / Compound	Weight share[1]	Weight share[2]
Carbon	~70%	70 - 75%
Hydrogen	7%	6 - 7%
Zinc oxide	1%	1.2 - 2%
Sulphur	1%	1.3 - 1.7%
Iron	16%	13 - 15%
Additives		3.5 - 5%
Oxygen	4%	
Nitrogen	0.5%	
Stearic acid	0.3%	
Halogens	0.1%	
Copper compounds	200ppm	
Cadmium	10ppm	
Chromium	90ppm	
Nickel	80ppm	
Lead	50ppm	

Left - Table 4: The chemical composition of tyres. **Source 1:** *'Bundesamt für Umwelt, Wald und Landschaft: Vollzugshilfe für die Lagerung, Behandlung und Verwertung von Altreifen'* (Altpneus) – Entwurf, Stand. 10 December **2003**. **Source 2:** H. Vest, *'Recycling of used car tyres,'* Gate Information Service / gtz, **2000** (www.gtz.de/gate/gateid.afp)

Hence the energetic utilisation of tyres has clearly a better CO_2 balance than the incineration of fossil fuels as the emission factor for coal is 96kg CO_2/TJ.

Influences on clinker quality

The use of tyres as an alternative fuel in cement production influences kiln operation and clinker composition.

Sulphur - Due to the high sulphur content the circulation of volatile salts increases and therefore the coating tendencies in the area of the kiln inlet and the lower cyclones also increase.

Iron - Normally the retention time for complete tyre burning in the kiln is long enough to convert the steel carcass into iron components that are incorporated into the clinker minerals. Therefore the alumina modulus decreases. This benefits the substitution of any corrective material, for example natural iron ore.

Zinc - The high concentration of zinc (approximately 1 – 2 %) in tyres is crucial. Levels up to 500ppm Zn in clinker do not impact the cement properties (H Braun).

The usual maximum substitution rate by using tyres is approximately 25% of the whole thermal energy consumption due to process engineering restrictions. Even then this high level of zinc in clinker is not achieved.

However, investigations show that zinc concentration above 500ppm in clinker impact the workability of cement. Small amounts of zinc, between 0.01 and 0.2% have been reported to increase the reactivity of the C_3A and in consequence lead to possible setting time problems, (LEA et al).

Zinc levels above 0.4 % increase setting time [Scrap Tire Management Council] and experiments on laboratory clinker and cement show a clear retarding effect at 2.5% of zinc in clinker, (D. Stephan).

Recommendations and considerations

1. Operators should ensure continuous mass flow into the feeding point of the kiln or calciner. This benefits the homogeneous combustion and hence the kiln operation. Continuous mass flow benefits the standard deviation of the iron oxide content of the clinker. The total iron oxide content consists of the iron oxide from raw meal plus the input from tyres. Normally the standard deviation of the raw meal is relatively low, and it increases while feeding whole tyres. The fluctuations of iron oxide in clinker become tremendous when tyre feeding is accidentally halted.

2. Winter operation with stored tyres in the open can lead to large amounts of water or ice trapped in the tyres. This changes the apparent feeding weight and impacts the calorific values and should be taken into account.

3. Operators should be careful about the total input of volatile elements (sulphur, sodium, potassium, chloride) from other alternative fuels and raw materials while using scrap tyres. The volatility will increase and hence cause coatings and cloggings.

4. Operators should be aware the resulting zinc content in the clinker, especially when phosphate levels are high. Setting time and early strength could be greatly affected.

5. Operators should be careful of the feeding point and particle size of sliced tyres. Experience shows that shredded tyres fed into the calciner can result in deposits of unreacted wires in the lowest-most cyclone. This results in cloggings of the meal outlet. The gas flow in the riser duct sweeps the tyre pieces away. The tyre pieces burn and become lighter, forming deposits. A more reliable feeding point is the meal chute of the second lower cyclone to the calciner. This feeding channels the pieces directly into the kiln inlet so that the exhaust flow cannot sweep the pieces along into the cyclones.

6. Although the wires and carcasses seem to be destroyed completely in the kiln, some cement plants experience small metal iron pieces that remain in the clinker. To combat this, operators can install magnetic separators positioned before the clinker is fed into the cement mill.