Alternative Fuels

Cement Consultancy Associates Limited (CCA) present an overview of the use of waste materials as a fuel in cement kilns based on their expertise and experience.

In the current depressed global economy many cement producers are experiencing severe financial difficulties and their focus has to be related more to finance and less to cement making. This is an extremely difficult situation for local plant management where limited capital investment has to return maximum benefits whilst continuously trying to improve reliability and productivity (without negative impacts on safety and the environment). Furthermore, at local level, cement plants are under pressure from national and urban administration to reduce environmental impact and make a positive contribution to the local and regional communities.

The treatment and disposal of industrial and household waste is now a major issue for developed and developing countries. Current waste management techniques no longer meet the demands and expectations of an environmentally aware global population where:

- recycling is only possible for certain types of waste;
- there is ever increasing pressure on landfill availability and costs of disposal; and
- incineration requires highly sophisticated environmental control and is very costly, especially where waste heat is not utilised.

Safe, environmentally sound and innovative solutions are required to reduce the huge masses of material taken to landfill or the operation of costly and controversial incinerators. Using certain waste streams as fuels within a cement kiln can be advantageous for both the cement plant operator and waste producers and management companies, and will result in the following benefits:

- a reduction in the quantities of material going to landfill;
- energy recovery from combustible wastes;
- conservation of fossil fuels;
- reduction in cement production costs; and
- improvement in environmental performance and reduction in acid gas stack emissions.

The necessity to pursue the reduction of fuel cost to ensure competitiveness has resulted in the development and use of an extensive range of waste derived fuels (WDF) suitable for combustion in the cement kiln. Furthermore the development of WDF offers the cement industry an opportunity to make a significant contribution to the quest for a sustainable society whilst at the same time remaining competitive.
Consequently Cement Consultancy Associates (CCA) would urge plant operators to develop an alternative fuel strategy that ensures continuity of supply, safe operation and cost reduction without detriment to production levels or quality.

**The cement kiln has an important role to play in recovery of waste**

In the developed world the rate at which waste is being produced far exceeds the present capacity for treatment and disposal in a safe and efficient manner, and in the long term this will give rise to significant environmental issues. Apart from the combustible element of a waste stream combustion products are generated which need further treatment before safe emission, and certain materials are not destroyed in the combustion process. CCA is aware that it is extremely expensive to design and construct new waste treatment and disposal facilities that mitigate against these factors; however, one of the advantages of using a cement kiln is that the facilities already exist and therefore this provides an attractive option for the beneficial recovery of large volumes of many types of waste streams.

The features of a cement kiln system that provide ideal conditions for burning wastes at low levels of emissions and residual by-products are discussed below.

**High combustion temperatures**

- The sintering zone flame temperature is normally in the range 1800–2200°C. At this temperature even very stable organic compounds are completely combusted without critical residues in either the clinker or exhaust gases. Inorganic compounds are locked into the clinker crystal structures. Secondary firing in the calciner combustion chamber, kiln inlet or riser duct occurs in the 800–1200°C range, which is suitable for most non-hazardous domestic and industrial waste streams. In association with high temperatures the cement kiln provides the opportunity for longer residence times at high temperature than the normal operating conditions of a typical waste incinerator.

**Contact with fine, dispersed raw meal**

- In the cement manufacturing process intensive contact between the hot combustion gases and raw meal is required as a condition for good heat transfer. The calcium oxide produced during calcination is alkaline which is extremely reactive and ideal for scrubbing acid combustion gases such as HCl and SO\(_2\). Contact between the hot gas and fine materials occurs in a counter-current manner and the gases leave at a fairly low temperature having been neutralised by the alkaline material in the kiln and raw mill systems.

**Low stack temperature**

- The final emission gas temperature is a key factor in the retention of possible pollutants. Condensation and absorption of volatile salts and metals occurs on the surface of the active raw meal and reduces their concentration. The effect strongly depends on the gas temperature; the lower the temperature the lower will be the concentration of volatile compounds in the gas emission. Rapid
cooling of the gases as they leave the preheater tower via the raw mill or the cooling tower prevents the formation of polychlorinated hydrocarbons.

**Highly efficient de-dusting equipment**
- A modern cement plant is equipped with highly efficient de-dusting equipment comparable to a modern incinerator. However, depending on the manufacturing process, the concentration of alkali salts or certain metals can build up in the kiln systems and a by-pass will be necessary so there may well be a requirement for a safe disposal of the by-pass dust.

**Safe disposal of non-destructible trace materials**
- Chemical elements, such as heavy metals, cannot be destroyed by the kiln pyro-processes. The cement kiln offers the unique opportunity to incorporate trace materials in the clinker production process. The large volume of production materials involved results in the concentrations of trace materials being very low in the kiln product and they are also brought to an insoluble state where they have no pollution potential. However, high levels of certain elements can adversely affect the setting time of cement; clinker should be closely monitored and the formulation of the WDF adjusted to maintain the concentration to an acceptable level.

**Thermal stability**
- The cement kiln is a large manufacturing unit with a high heat capacity and a significant change in kiln temperature over a short time is not possible. Consequently, if an upset to normal operating conditions occurs, the waste in the kiln will still be adequately destroyed.
- Interlocks and permissive controls can be installed in the kiln SCADA system to automatically control waste fuel feeds in the event of a kiln upset.

**Waste derived fuels used in the cement industry**
If the waste stream is to be used as a suitable WDF, it must be combustible and have significant energy content. Typically, WDF derived from domestic waste will have a calorific value (CV) possibly less than 15MJ/kg, whereas tyres or liquid fuels based on waste oils or solvents will have a CV equal to or better than conventional fossil fuels at 30MJ/kg. CCA would recommend that a cement production facility avoids using a waste stream as a fuel if it is corrosive, reactive or highly toxic unless it is also combustible with significant energy content; however, users should be aware that investment costs will be much higher.

<table>
<thead>
<tr>
<th>Actual CVs as used on a cement kiln</th>
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</thead>
<tbody>
<tr>
<td><strong>Fuels</strong></td>
</tr>
<tr>
<td>Conventional</td>
</tr>
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<td></td>
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</tbody>
</table>
### Waste derived

<table>
<thead>
<tr>
<th>Material</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoil/diesel</td>
<td>41.28</td>
</tr>
<tr>
<td>Scrap tyres</td>
<td>29.74</td>
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<tr>
<td>Waste oil</td>
<td>35.00</td>
</tr>
<tr>
<td>Solvent fuels</td>
<td>22.26</td>
</tr>
<tr>
<td>Paper plastic</td>
<td>17.02</td>
</tr>
<tr>
<td>Animal meal</td>
<td>17.00</td>
</tr>
<tr>
<td>Shale</td>
<td>6.50</td>
</tr>
</tbody>
</table>

Other issues, as well as combustibility and energy content, may render the waste stream unsuitable for use as a fuel. Organic materials with high levels of chlorine, when burned in a cement kiln, create difficulties in the process due to the formation of alkali salts which condense in the cooler parts of the kiln system and cause build up and blockages; a by-pass can be used to accommodate such fuels. Also, as discussed previously, trace elements that are combined in the clinker matrix can adversely affect cement setting times.

In CCA’s experience the first 10% replacement of conventional fuels by waste fuels is easy; as the replacement percentage increases so the issues of burner design, residence time, fuel chemistry, ash analysis and use of a portfolio of waste fuels become important. However, CCA has observed that regular replacement at the 70 to 80% level can be achieved if these factors are considered carefully.

We need to note that some issues will affect the kiln capacity, particularly on kiln systems which are fan limited:

- high water content of the waste stream produces a larger volume of exhaust gas;
- waste will usually have a higher ash content than traditional fuels resulting in less material through the system and a higher gas exhaust temperature;
- increased $O_2$ content in kiln gases to ensure complete burn out of waste materials;
- when wastes are injected pneumatically or fed by chute additional cold air in-leak will occur.
Liquid fuels

Liquid WDF is the easiest of the alternative fuels to transport, store, blend and inject into the kiln system. Liquid fuels generally take the form of blends of waste oils and sludges from refineries, solvents and slurries from printing and paint industries or wastes from the chemical industry (waste oil CV is generally in the range 30–38 MJ/kg while paint sludges etc may be as low as 18 MJ/kg). Other liquid waste streams that are available are classified as extremely toxic and include solutions containing PCBs and PAHs, but these are generally unsuitable for combustion in a cement kiln due to the high levels of chlorine and lower CV.

- The plant and equipment required to dose liquid fuels into the kiln system include:
  - bunded tank farm with reception tanks and blended fuel tanks fitted with stirrers and carbon filters for odour control;
  - pumped blending system including a macerator for size reduction of the solid fraction in the waste, strainers and filters;
  - dosing pumps with flow monitoring and control and stainless steel pipework to transport to the injection point;
  - injection into the kiln, generally in the centre of the main burner, using air or pressure atomisation.

Solvent fuel storage tanks
Solid fuels

Solid waste streams suitable for use in a cement kiln can come from many sources:

- tyres, whole and shredded (CV 28–32MJ/kg);
- domestic refuse, which is usually sorted to remove the organic content then shredded, or undergoes a mechanical and biological treatment (MBT) to produce a compost (CV 10–15MJ/kg depending on moisture content);
- industrial refuse from packaging and plastics, and wastes from car, furniture and carpet production, also sorted and shredded to a size suitable for kiln combustion (CV 10–15MJ/kg depending on moisture content);
- natural materials such as palm nut shells, pressed olive cake, bark and wood chips, coconut shells, rice husks etc. (CV 16–20MJ/kg);
- dried sewage sludge (CV 10MJ/kg);
- meat and bone meal (MBM) (CV 18–20MJ/kg).

Conventional storage and handling equipment can be used to feed most solid WDF into the kiln system. The lighter and more moisture absorbent fuels derived from domestic or industrial refuse generally need to be stored in covered buildings to prevent deterioration and dispersion into the local area. In some cases, where full automation of the process is required, the floors of the storage area/building have push floors to transport material onto the conveying system, but loading shovels can be used to blend material and load into feed hoppers as a less expensive alternative.

For the heavier waste materials dosing is normally into the kiln inlet, riser duct or calciner combustion chamber. The feed rate is controlled by a weigh-belt feeder and either conveyed to a rotary valve or multiple flap valve to isolate the conveying system from the hot gases. The lighter materials can be pneumatically conveyed to either the main burner or secondary burner and injected either alongside or within the burner tube.
Sewage sludge and MBM are more difficult to handle due to moisture content and inherent oils and fats, and can have particularly pungent odours. These materials are normally delivered in tankers, stored in silos with sophisticated extraction devices and conveyed in totally enclosed systems. Vent air from silos can be used as primary air in the burners to prevent odours escaping into the environment.

**Kiln system waste fuel injection points**

**Benefits of burning waste derived fuels in a cement kiln**

The major benefit from using WDF in a cement kiln is one of reduction of operating costs by the direct replacement of expensive non-renewable fossil fuel with alternative fuels which are substantially cheaper, zero cost or can provide income (gate fees) in certain circumstances. Recently CCA consultants have assisted cement plants with their alternative fuels strategies to achieve benefits of $5 to $10 per tonne of clinker produced (based on EU fuel costs). At this high level of return, investment payback periods are of the order of months, rather than years, especially at the current low level of interest rates.

Apart from the financial savings a further advantage of using WDF is the conservation of non-renewable fossil fuel resources such as coal and oil. Maximising
the use of waste as fuels avoids emissions of greenhouse gases from landfill and incineration. Generally WDF have a lower carbon content than conventional fuels such as coal or HFO, thus in those regions where emission trading or carbon offsetting is the rule there are further opportunities for the generation of additional funds. Where the fuels contain biomass, the biomass content is not included in the emission trading schemes.

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Actual emission factor (kgCO₂/TJ of energy)</th>
<th>Biomass content (%)</th>
<th>Effective emission factor (kgCO₂/TJ of energy)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>96.00</td>
<td>0</td>
<td>96.00</td>
</tr>
<tr>
<td>Pet coke</td>
<td>100.00</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>Gasoil/diesel</td>
<td>65.47</td>
<td>0</td>
<td>65.47</td>
</tr>
<tr>
<td><strong>Waste derived</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scrap tyres</td>
<td>85.10</td>
<td>22</td>
<td>66.12</td>
</tr>
<tr>
<td>Waste oil</td>
<td>65.47</td>
<td>0</td>
<td>65.47</td>
</tr>
<tr>
<td>Solvent fuels</td>
<td>75.00</td>
<td>0</td>
<td>75.00</td>
</tr>
<tr>
<td>Paper plastic</td>
<td>80.00</td>
<td>55</td>
<td>36.00</td>
</tr>
<tr>
<td>Animal meal</td>
<td>72.00</td>
<td>100</td>
<td>0.00</td>
</tr>
<tr>
<td>Shale</td>
<td>95.00</td>
<td>0</td>
<td>95.00</td>
</tr>
</tbody>
</table>

The vast quantities of waste being generated worldwide have significant energy content and this is obviously one of the primary reasons for the cement industry’s interest in burning WDF. The waste is burned in a manufacturing process and therefore the energy value of the waste is recovered and it can be argued that this energy transfer is re-cycling or resource recovery disposal.

One of the advantages of using cement kilns is that the technology and facilities already exist. Hence the costs of construction of new waste incineration plants are avoided, and because the creation of an additional source of emission is unnecessary the net effect is an environmental benefit.

It is absolutely certain that environmental authorities will not relax emission standards to plants using WDF. However there is good operational evidence to support that, with some types of fuel, there is a reduction in NOₓ levels in the stack gases.

**Development of an alternative fuel strategy**
Before a cement plant can embark on a campaign to use waste derived fuels as part of its fuel strategy certain technical, management and community issues have to be resolved in order to ensure that a viable, sustainable and financially beneficial solution can be found. The following areas have to be evaluated and implemented in relation to the particular cement plant, the local community’s perceptions and culture, safety and environmental legislation.
The availability of ready prepared and sorted WDF, which will depend on the maturity of the local waste markets and of the regional waste disposal laws and controls. Cement companies can play an active role in proposing safe and environmentally sound disposal routes.

Survey and analysis of available waste streams – types, quantities and qualities available, location, reliability and consistency, infrastructure and transport.

Process analysis – determination of existing kiln performance, types of raw materials and fuels used, modelling to determine the influence on kiln performance of other fuels.

Specifications for WDF – based on the waste and process analysis.

Feasibility studies – capital investment costs versus financial benefits.

Environmental impact assessment and risk analysis in support of license applications and permissions.

Quality control procedures – analysis and reporting of fuels, emissions, clinker and cement products, demonstration of regulatory compliance.

Design of fuel reception, storage, blending and dosing systems.

Specifications for the process, equipment, control system philosophy, interlocks and control algorithms.

Operational trials of WDF – comparison with process analysis, influence on production and quality, determination of operating range of fuel.

Operational procedures and safety training – determination of actions required during normal and abnormal conditions.

Liaison with local communities and national authorities – stage by stage discussion with all parties to develop a good working relationship.

The use of waste derived fuels in cement kilns as part of a total fuels strategy has significant financial benefit for the plant operator. Furthermore waste producers, waste management companies and local authorities responsible for waste disposal can take advantage of this option rather than using expensive waste incinerators or over-used landfill sites.

However the transition to the use of waste derived fuels by cement plant operators needs careful consideration, analysis, management and technical support to implement the various stages required to realise the full potential of this valuable fuel source.

Cement Consultancy Associates has the expertise to provide a range of professional and technical services to assist operators in the smooth transition of an alternative fuels policy into the day-to-day operation of a cement plant during the globally competitive, financially restrictive first decade of the 21st century.