

Annexure I – SLS & BSEN standards related to cement

Both chemical and physical properties are specifically mentioned by SLS & BSEN standards. Quality assurance teams use the most stringent criteria during production in order to maintain the both standards.

Table 6-2: Physical & chemical properties required by SLSI

Parameter	SLS 1253:2003	SLS 515:2003	SLS 107:2008
Physical parameters			
Compressive strength 2 days [N/mm ²]	NA	NA	>10
Compressive strength 3 days [N/mm ²]	>20	NA	NA
Compressive strength 7 days [N/mm ²]	NA	>10	NA
Compressive strength 28 days [N/mm ²]	40 – 62.5	>22.5	42.5-62.5
Setting time – initial [mins]	>45	>60	>60
Setting time – Final [mins]	<600	<600	NA
Fineness [cm ² /g]	>3300	>400	>225
Soundness [mm]	<10	<10	<10
Chemical Properties			
SO ₃ [%w/w]	<3.5	<3.0	<3.0
Loss of ignition [%w/w]	<11	NA	<0.1
Chloride [%w/w]	<0.1	<0.1	<5.0
Fresh mortar properties			
Water retention [m/m%]	NA	80-95	NA
Air content [v/v%]	NA	<6.0	NA
Flow [%]	NA	80-120	NA

(SLS , 2008), (SLS , 2008), (SLS , 2008)

HLL product portfolio related BSEN product quality standards are as below.

Table 6-3: Physical & chemical properties required by BSEN

Parameter	BS EN 197-1:2000	BS EN 413-1:2004
Physical parameters		
Compressive strength 2 days [N/mm ²]	>10	NA
Compressive strength 7 days [N/mm ²]	NA	>10
Compressive strength 28 days [N/mm ²]	<42.5	>12.5
Setting time – initial [mins]	>60	>60
Soundness [mm]	<10	<10
Chemical Properties		
SO ₃ [% w/w]	<3.5	<3.0
Chloride [% w/w]	<0.1	0.10
Fresh mortar properties		
Water retention [m/m%]	NA	>75
Air content [v/v%]	NA	<6.0

Source (HLL, 2009)

Annexure II – Wet kiln and dry kiln processes

From the earliest times, two different methods of raw mix preparation were used: the mineral components were either dry-ground to form a flour-like powder, or wet-ground with added water to produce a fine slurry with the consistency of paint, and with a typical water content of 40–45%.

The wet process suffered the obvious disadvantage that, when the slurry was introduced into the kiln, a large amount of extra fuel was used in evaporating the water. Furthermore, a larger kiln was needed for a given clinker output, because much of the kiln's length was used up for the drying process. On the other hand, the wet process had a number of advantages. Wet grinding of hard minerals is usually much more efficient than dry grinding. When slurry is dried in the kiln, it forms a granular crumble that is ideal for subsequent heating in the kiln. In the dry process, it is very difficult to keep the fine powder raw mix in the kiln, because the fast-flowing combustion gases tend to blow it back out again. It became a practice to spray water into dry kilns in order to "damp down" the dry mix, and thus, for many years there was little difference in efficiency between the two processes, and the overwhelming majority of kilns used the wet process. By 1950, a typical large, wet process kiln, fitted with drying-zone heat exchangers, was 3.3 x 120 m in size, made 680 tonnes per day, and used about 0.25–0.30 tonnes of coal fuel for every tonne of clinker produced. Before the energy crisis of the 1970s put an end to new wet-process installations, kilns as large as 5.8 x 225 m in size were making 3000 tonnes per day. An interesting footnote on the wet process history is that some manufacturers have in fact made very old wet process facilities profitable through the use of waste fuels. Plants that burn waste fuels enjoy a negative fuel cost (they are paid by industries needing to dispose of materials that have energy content and can be safely disposed of in the cement kiln thanks to its high temperatures and longer retention times). As a result the inefficiency of the wet process is an advantage—to the manufacturer. By locating waste burning operations at older wet process locations, higher fuel consumption actually equates to higher profits for the manufacturer, although it produces correspondingly greater emission of CO₂.

However with the new cement kiln technology improvements there are more types introduced. Mainly this is due to optimize the heat consumptions and reduce unnecessary emissions.

There are four types of kilns in use - long wet kilns, long dry kilns, kilns with a preheater and kilns with a precalciner. The long wet and dry kilns and most preheater kilns have only one fuel combustion zone, whereas the newer precalciner kilns and preheater kilns with a riser duct have two fuel combustion zones. In a wet kiln, the ground raw materials are suspended in water to form a slurry. In a dry kiln, the raw materials are dried to a powder. Newer U.S. cement plants normally use the dry process because of its lower energy requirement. Because the typical operating temperatures of these kilns differ, the NO_x formation mechanisms also differ among these kiln types. In a primary combustion zone at the hot end of a kiln, the high temperatures lead to predominantly thermal NO_x formation. In the secondary combustion zone, however, lower gas-phase temperatures suppress thermal NO_x formation. Energy efficiency is also important in reducing NO_x emissions; for example, a high thermal efficiency means less heat and fuel are consumed and, therefore, less NO_x is produced. (STAPPA, ALAPCO, 1994)

Wet process kilns

The original rotary cement kilns were called 'wet process' kilns. In their basic form they were relatively simple compared with modern kilns. The raw meal was fed into the kiln at ambient temperature in the form of a slurry.

A wet process kiln may be up to 200m long and 6m in diameter. It has to be long because a lot of water has to be evaporated and the process of heat transfer in a wet process kiln is not very efficient.

The slurry may contain about 40% water. This takes a lot of energy to evaporate and various developments of the wet process were aimed at reducing the water content of the raw meal. An example of this is the 'filter press' (imagine a musical accordion 10-20 metres long and several metres across) - such adaptations were described as 'semi-wet' processes.

The wet process has survived for over a century because many raw materials are suited to blending as a slurry. Also, for many years, it was technically difficult to get dry powders to blend adequately.

Quite a few wet process kilns are still in operation, usually now with higher-tech bits bolted on. However, new cement kilns are of the 'dry process' type.

Dry process kilns

In a modern works, the blended raw material enters the kiln via the pre-heater tower. Here, hot gases from the kiln, and probably the cooled clinker at the far end of the kiln, are used to heat the raw meal. As a result, the raw meal is already hot before it enters the kiln.

A dry process kiln is much more thermally efficient than a wet process kiln.

Firstly, and most obviously, this is because the meal is a dry powder and there is little or no water that has to be evaporated.

Secondly, and less obviously, the process of transferring heat is much more efficient in a dry process kiln.

An integral part of the process is a heat exchanger called a 'suspension preheater.' This is a tower with a series of cyclones in which fast-moving hot gases keep the meal powder suspended in air. All the time, the meal gets hotter and the gas gets cooler until the meal is at almost the same temperature as the gas.

The basic dry process system consists of the kiln and a suspension preheater. The raw materials, limestone and shale for example, are ground finely and blended to produce the raw meal. The raw meal is fed in at the top of the preheater tower and passes through the series of cyclones in the tower. Hot gas from the kiln and, often, hot air from the clinker cooler are blown through the cyclones. Heat is transferred efficiently from the hot gases to the raw meal.

The heating process is efficient because the meal particles have a very high surface area in relation to their size and because of the large difference in temperature between the hot gas and the cooler meal. Typically, 30%-40% of the meal is decarbonated before entering the kiln.

A development of this process is the 'precalciner' kiln. Most new cement plant is of this type. The principle is similar to that of the dry process preheater kiln but with the major addition of another burner, or precalciner. With the additional heat, about 85%-95% of the meal is decarbonated before it enters the kiln. (Understanding-cement, 2010)

Below Figure 6-9 shows the process technology shifting of cement kilns from wet

kilns to dry kilns by selecting the CSI member cement plants.

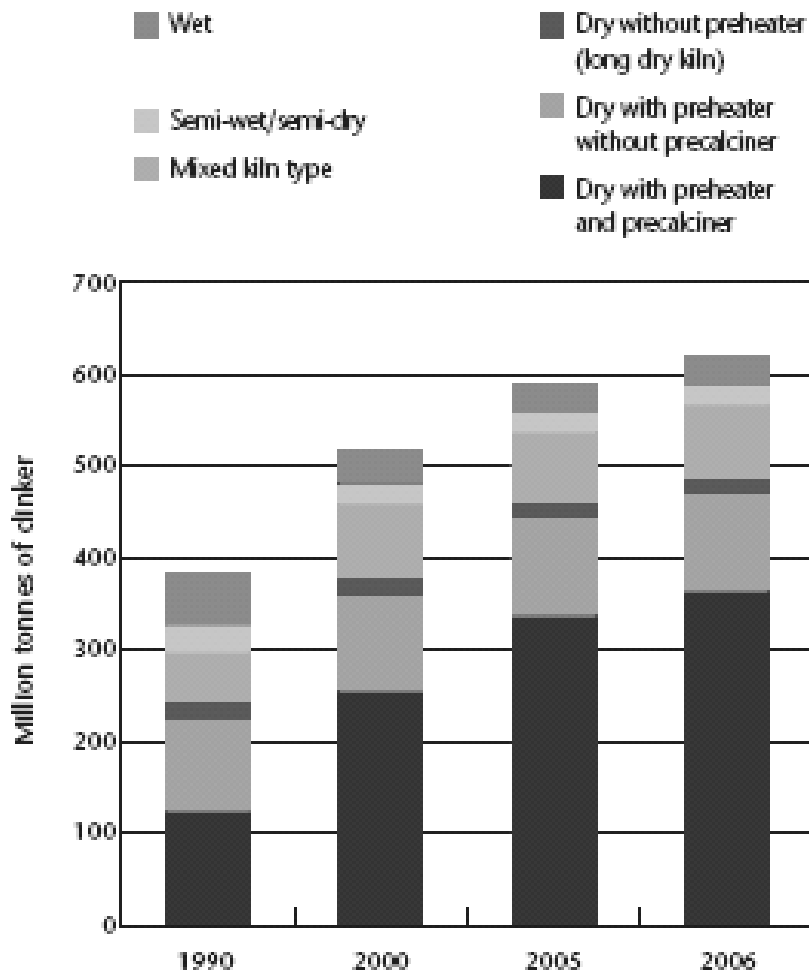


Figure 6-9: Clinker volumes by technology

Source: (WBCSD, 2008)

Annexure III - A brief history of LCA

Life Cycle Assessment (LCA) had its beginnings in the 1960's. Concerns over the limitations of raw materials and energy resources sparked interest in finding ways to cumulatively account for energy use and to project future resource supplies and use. In one of the first publications of its kind, Harold Smith reported his calculation of cumulative energy requirements for the production of chemical intermediates and products at the World Energy Conference in 1963. (Scientific Applications International Corporation (SAIC), 2006)

Later in the 1960's, global modeling studies published in *The Limits to Growth* (Meadows *et al* 1972) and *A Blueprint for Survival* (Goldsmith *et al* 1972) resulted in predictions of the effects of the world's changing populations on the demand for finite raw materials and energy resources. The predictions for rapid depletion of fossil fuels and climatological changes resulting from excess waste heat stimulated more detailed calculations of energy use and output in industrial processes. During this period, about a dozen studies were performed to estimate costs and environmental implications of alternative sources of energy.

In 1969, researchers initiated an internal study for The Coca-Cola Company that laid the foundation for the current methods of life cycle inventory analysis in the United States. In a comparison of different beverage containers to determine which container had the lowest releases to the environment and least affected the supply of natural resources, this study quantified the raw materials and fuels used and the environmental loadings from the manufacturing processes for each container. Other companies in both the United States and Europe performed similar comparative life cycle inventory analyses in the early 1970's. At that time, many of the available sources were derived from publicly-available sources such as government documents or technical papers, as specific industrial data were not available.

The process of quantifying the resource use and environmental releases of products became known as a Resource and Environmental Profile Analysis (REPA), as practiced in the United States. In Europe, it was called an Ecobalance. With the formation of public interest groups encouraging industry to ensure the accuracy of

information in the public domain, and with the oil shortages in the early 1970's, approximately 15 REPAs were performed between 1970 and 1975. Through this period, a protocol or standard research methodology for conducting these studies was developed. This multi-step methodology involves a number of assumptions. During these years, the assumptions and techniques used underwent considerable review by EPA and major industry representatives, with the result that reasonable methodologies were evolved.

From 1975 through the early 1980's, as interest in these comprehensive studies waned because of the fading influence of the oil crisis, environmental concerns shifted to issues of hazardous and household waste management. However, throughout this time, life cycle inventory analysis continued to be conducted and the methodology improved through a slow stream of about two studies per year, most of which focused on energy requirements. During this time, European interest grew with the establishment of an Environment Directorate (DG X1) by the European Commission. European LCA practitioners developed approaches parallel to those being used in the USA. Besides working to standardize pollution regulations throughout Europe, DG X1 issued the Liquid Food Container Directive in 1985, which charged member companies with monitoring the energy and raw materials consumption and solid waste generation of liquid food containers.

When solid waste became a worldwide issue in 1988, LCA again emerged as a tool for analyzing environmental problems. As interest in all areas affecting resources and the environment grows, the methodology for LCA is again being improved. A broad base of consultants and researchers across the globe has been further refining and expanding the methodology. The need to move beyond the inventory to impact assessment has brought LCA methodology to another point of evolution (SETAC 1991; SETAC 1993; SETAC 1997).

In 1991, concerns over the inappropriate use of LCAs to make broad marketing claims made by product manufacturers resulted in a statement issued by eleven State Attorneys General in the USA denouncing the use of LCA results to promote products until uniform methods for conducting such assessments are developed and a consensus reached on how this type of environmental comparison can be advertised non-deceptively. This action, along with pressure from other environmental

organizations to standardize LCA methodology, led to the development of the LCA standards in the International Standards Organization (ISO) 14000 series (1997 through 2002).

In 2002, the United Nations Environment Programme (UNEP) joined forces with the Society of Environmental Toxicology and Chemistry (SETAC) to launch the Life Cycle Initiative, an international partnership. The three programs of the Initiative aim at putting life cycle thinking into practice and at improving the supporting tools through better data and indicators. The Life Cycle Management (LCM) program creates awareness and improves skills of decision-makers by producing information materials, establishing forums for sharing best practice, and carrying out training programs in all parts of the world. The Life Cycle Inventory (LCI) program improves global access to transparent, high quality life cycle data by hosting and facilitating expert groups whose work results in web-based information systems. The Life Cycle Impact Assessment (LCIA) program increases the quality and global reach of life cycle indicators by promoting the exchange of views among experts whose work results in a set of widely accepted recommendations.

Annexure IV – Bag filter mechanism

The dust-laden air enters the bag filter bustle. The air is uniformly distributed avoiding channeling. Initially a coat of material forms on the bags. Subsequently, the coat acts as the filtering medium. The dust is accumulated on filter elements while the air passes through the filter bags from outside to inside. The accumulated powder is dislodged from the bags by reverse pulse-jet air intermittently. The dislodged powder falls on bottom cone and is discharged through powder discharge valves. The dust free air is sucked by induced draft fan and is exhausted to atmosphere (Figure 6-10). Knockers are provided on conical portion especially for sticky/hygroscopic materials. In a cement plant there are number of these installations and Figure 2-17 shows a set up de-dusting units fixed on blending silos at PCW – HLL. (Transparency Technology Pvt Ltd, 2009)

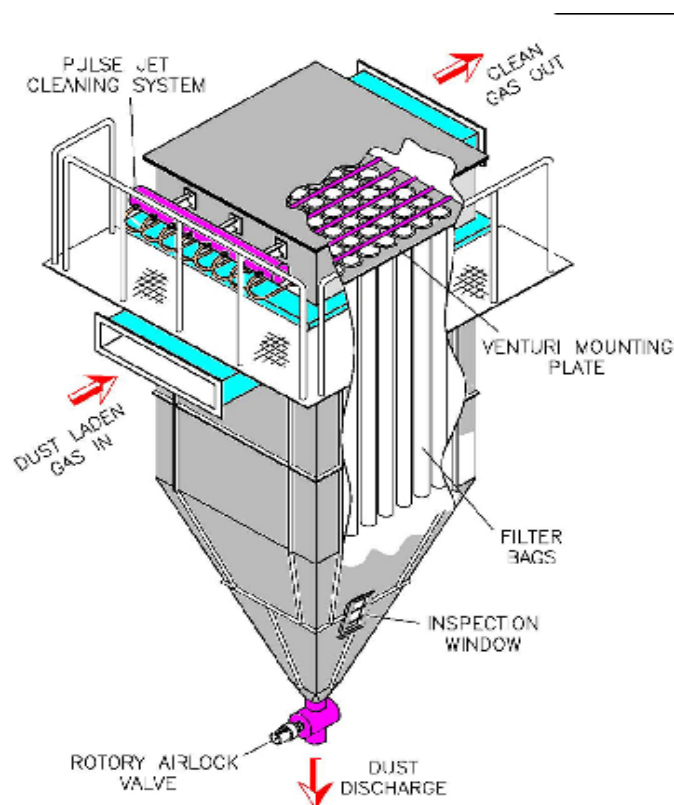


Figure 6-10: Typical bag filter unit in cement plants

Annexure V – Non CO₂ emission monitoring

Gaseous emissions other than CO₂ are also significant environmental impacts in cement manufacturing process. Emissions of SO₂, NO_x and VOC's are mostly common emission parameters which is given similar importance to GHG emissions in cement industry. However these three gaseous emissions are depended on raw material source, fuel composition and the specific process technology.

HLL PCW has invested and installed a continuous emissions monitoring (CEMs) system to monitor twelve important emission parameters including above three parameters. The availability and the accuracy is maintained and annually validated by a third party accredited test house.

While focusing on the GHG emission impacts in cement manufacturing some of the gaseous emissions were monitored as discussed in Table 6-4 below. LCIA phase these emission parameters also presented in the specific figures. HLL has already reported in publicly these parameters demonstrating the corporate transparency.

Table 6-4: Gaseous Emissions parameters monitored through CEMs

Parameters	Measuring Device(s)	Reporting Units	Measuring frequency
Dust (PM)	CEMs : FW101 Units	mg/Nm ³ (@ 10% O ₂)	Continuous
VOC's (Volatile Organic Compounds)	CEMs : FID (Flame Ionization Detector)	mg C/Nm ³	
CO, SO ₂ , NO _x as NO ₂ (In cement kilns NO _x is reported as NO as NO ₂ , hence the NO also converted to NO ₂) HCl, NH ₃	CEMs: MCS100E	mg/Nm ³ (@ 10% O ₂)	

Table 6-5: Gaseous parameters monitored and reported annually

Parameters	Measuring Methodology	Reporting Units	Measuring frequency	Remarks
Heavy Metals in gaseous phase	Method : USEPA 29	mg/Nm ³ (@ 10% O ₂)	Annually	A certified test house is occupied
Benzene	NIOSH - 1501	mg/Nm ³ (@ 10% O ₂)		
Dioxin & Furans	EPA Method - 23a	ngTEQ/Nm ³ (TEQ = Toxic equivalent)		

Annexure VI – Detail material & energy flow of cement manufacturing process

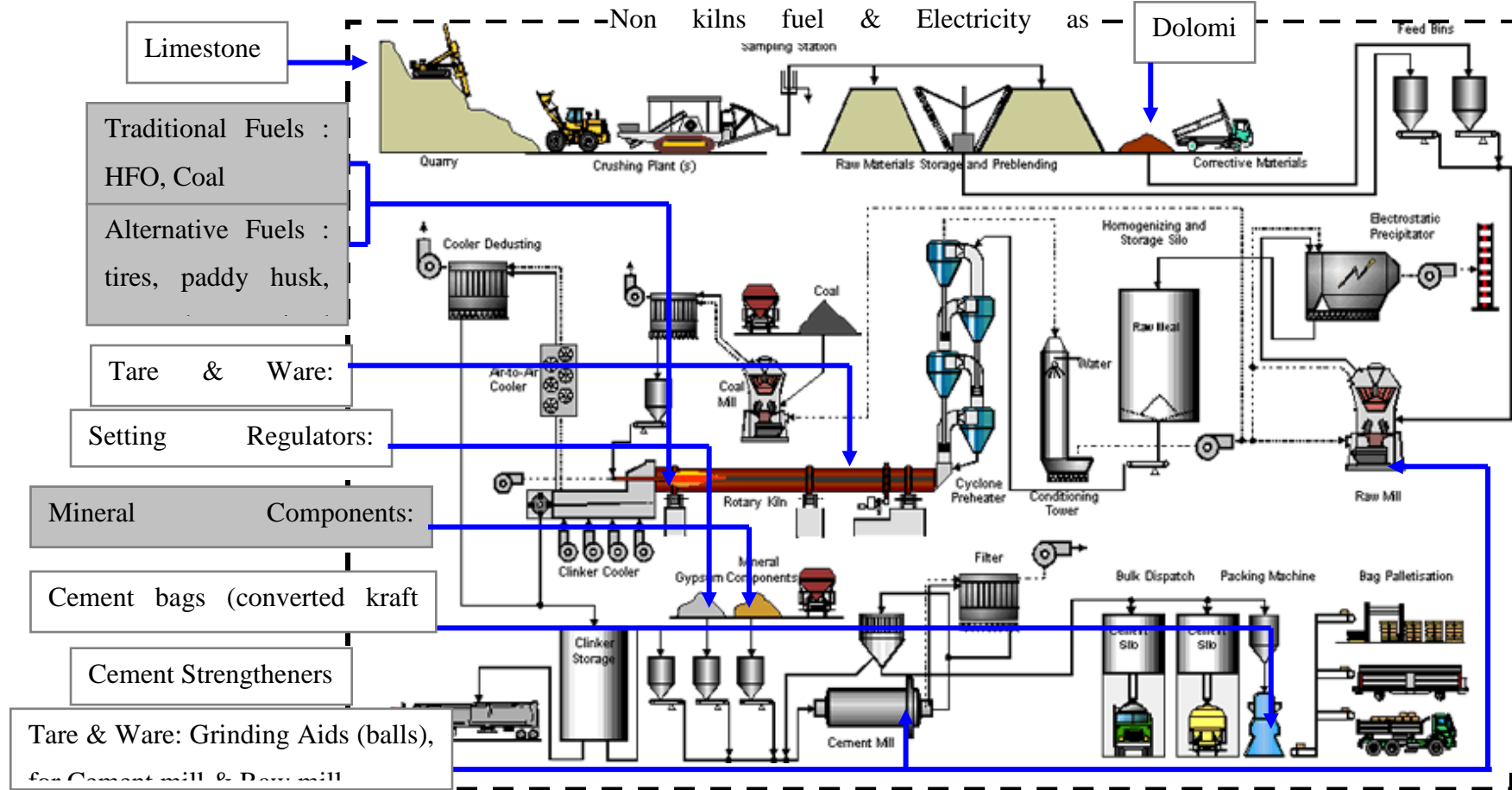


Figure 6-11: Material and energy input stages at HLL - PCW

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