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STRUCTURAL ASSET MAINTENANCE IN CEMENT PLANTS

1. Production Maintenance

Most cement plants have a high level of maintenance. This statement refers to "production maintenance", which would essentially cover plant equipment: mechanical, electrical and control/automation systems.

It is rather straightforward: maintenance related to production has an influence on the financial results of a company, either through increased output or through lower unit costs: therefore, it is reasonable to find that resources are made available for maintenance (production maintenance).

Unfortunately, the "good" maintenance (predictive as opposed to emergency repairs) falls within a trap: its purpose is that no effects are perceived. A good maintenance outcome would be the lack of breakdowns - but it is much easier to notice a breakdown, than the lack of disturbances.

Maintenance also involves a certain delay between actions and results: things do not fall apart the day after the preventive maintenance is cancelled, or production does not spike after a predictive maintenance action. And thus, in case of financial constraints (and there are always financial constraints!) production maintenance can also be neglected. This we find in many cement plants all over the world: a tight dispute for scarce financial resources, where maintenance is in the weak side.

If this is happening with production maintenance, what is occurring to "non-production" maintenance? But, first: what is "non-production" maintenance?

Figure 1: From running plants with low (design and) maintenance standards

2. "Non-production" Maintenance

The most visually outstanding features of an integral cement plant are likely the preheater tower, the raw material and finished products storage systems, and the quarry. In all them important production processes take place, and in all them the equipment or the machines are supported, functionally and physically, by structures and infrastructures. The steel or concrete tower of the preheater tower and its foundations; the domes, silos or warehouses storing the materials; the slopes, benches, channels, pits and tracks of the quarry; the roads providing access to the customers. All these are examples of elements that are indirectly related to the clinker and cement manufacturing, and which are necessary for that production. These assets also require a specific maintenance, a part of what we are calling "non-production" or "auxiliary" maintenance.

Fact is that the link between maintenance of structures and financial results is even weaker than for production maintenance. The main reason is that structures and similar elements are fixed assets whose deterioration is slow and failures are not that frequent. The common, perhaps underlying, argumentation would be something like this:

> "Well, if these structures have supported the loads for the last (__) years, why should they collapse now?".

So, based on experience there is always an additional confidence that the structures will continue supporting the loads - and in this case, there would be no need to place resources into their maintenance.

This is probably a valid explanation, but I would venture a parallel one, based on the tendency to disregard what is uncommon and what we are not familiar with: even when the bad condition of the structures is obvious at plain sight (or with hindsight), it is the potentially large investment and difficulties involved in the structural maintenance or substitution of something which is "ancillary" what helps keeping the managers blind to the reality of the bad condition of the very basic elements which are supporting their production, and their bottom line.

It also happens that cement plants often lack in-house expertise and guidance on structural maintenance: confronted with a slowly growing problem which does not seem urgent, with the confidence of the past, and without guidance to follow on the subject, the manager continues with all her other problems … until often it is too late.

All very human, but ...

3. Some Figures

It may be sobering to remember that the worldwide annual cost of corrosion is estimated to be around 5% of global GDP. Of course, this is just a general estimation with reported figures ranging from 3 to 6% - but the amount is nonetheless huge.

> **The worldwide annual cost of corrosion is estimated to be ~5% of global GDP.**

There is a rhetorical question which may be worthy presenting: with regard to corrosion, how far is an average cement plant from an average world asset which losses 5% of its output per year?

It is difficult to give a specific answer, which in any case would cover a wide range of circumstances, but I assume that it wouldn't be totally astray to take as a baseline at least that worldwide average, just for corrosion.

But I just mentioned the case in which the structural damages were accumulating without maintenance, until it was not more possible to avoid confronting them.

In the best case that would require a probably large expenditure of resources concentrated in a particular year - compared to likely a much more moderate sum spent periodically.

It is worth recalling that there is a **"rule of five" in civil maintenance**:

> 1 USD spent on durability during the design stage is equivalent to 5 USD spent for preventative maintenance later, which in turn is cheaper than 25 USD spent on corrective work.

This is only a "rule of thumb", but its underlying principles are valid.

So, in the best case it will be just a question of spending perhaps five times more money in a repair project, in the future, than in routine maintenance along the years. And this is just for direct expenses.

Note that a law of five is difficult to beat by NPV with ordinary discount rates, so the financial appeal of structural maintenance is hard to dismiss, although there may even be valid intermediate maintenance strategies.

So: in the best case denying structural maintenance is likely a bad financial choice. But, which is then the worst case?

Figure 2: From a real case

4. Worst Cases

Worse cases would be those in which accidents happen. The range is also wide: from just partial collapses with no further consequences, damages which affect production, structural accidents involving persons.

But … does this really occur?

Well, a Google search with the terms "industrial structural collapse cement plant" has raised several hundred thousand results in my computer [Jul'17]. The four non-repeated first ones were the following:

- Silo collapses at (…) Cement plant in (…). A raw meal silo has collapsed at (…). The structure containing 25,000t of raw material collapsed (…) also causing damage to the coal mill area of second production line. The company reported no casualties. [May 2016].
- Two cement silo collapses, four dead. Last week, (…) looked at (…) collapsed silo at (…). Two other cement silo collapses this year have had far deadlier results. [July 2015].
- Four workers die at (…) cement plant. Four workers have died when the roof of a shed collapsed at the (…) cement plant in (…). Three workers died at the scene and another died in hospital. [March 2017].
- Mine Safety and Health Administration blames management of (…) Cement for fatal accident at (…) plant. The Mine Safety and Health Administration has blamed the management of (…) Cement's policies, procedures and controls for the

death of a worker at its (…) cement plant (…). [December 2016].

Figure 3: From a real case

5. Reasons for Structural Failures

It is not possible in this document to detail all the possible reasons for a serious structure failure, and there will always be a number of contributory factors.

It is a common belief that failures happen suddenly with little or no warning: this generally is not the case, as usually the structure will have shown signs of distress for a period of time until those are too obvious or finally caused the structure to fail. True: bad designs, or sudden overloads and collapses occur, but it is more frequent the steady overload and degradation of the structural capacity.

Time, weather, overload and usage all are contributors to the degradation of industrial structures. This degradation can eventually translate into structural failure with the potential of becoming catastrophic. There are many signs of degradation, the failures observed are different in concrete and metal structures, and also vary depending on the aggressive agent, but there is a basic common behaviour: stresses and strains show-up as cracks and deformations, corrosion appears as tainted product and delamination and cracks.

Many of these failures are easily preventable through routine inspection which would detect the distresses, and an early maintenance can address the issues before they become larger. Many structural issues can be easily and economically addressed if detected in time. As stated earlier when discussing the "rule of five", prevention is the most cost-effective way to ensure the long-term integrity of concrete and metal structures. A proactive inspection and maintenance program is crucial to extend the life of bins, silos and structures to ensure the safety of those working around them and to maximise the life of a factory's assets.

However, a simple visual inspection is not always enough for a complete understanding of the structural integrity of elements that have been in service for several years. Depending on the deterioration and problems observed as well as the type of structure, it may be necessary to conduct more comprehensive studies.

6. Some Steps Forward

Just like "production maintenance", the maintenance of civil assets is more efficiently done following a tested and structured method. And this is even more necessary when a plant decides to move from the "ad hoc" emergency solutions to a systematic asset management.

The initial implementation, and even more the creation, of a civil assets maintenance program is best managed as a project which, once developed, is handed over to plant operations. Central elements of this project approach are:

- The decision. A civil maintenance plan can be put in place by a plant manager or even by a maintenance manager. However, as it involves basic assets of the company, it is a long-term activity, it will require resources, and it may be replicated in other plants, the decision is preferably coming from the company's top management. Experience also shows that otherwise it is difficult to take-off.

- A definition. Procedures, inventories and assessment reports will follow as the project is developed, but it is convenient that the "decision to proceed" provides a general framework, or a general policy, for the scope of work to be developed. It is relevant to clearly separate the project (start-up and launching) from the operations (the plant's routine maintenance activities).
- Resources. This would typically involve an organization with a Client, assisted or not by a Steering Committee, a Project Manager, and a Project Team, usually with plant staff and external consultants. Resources should also be allocated to the organization, at least regarding time and finance.
- The inventory. A list of elements to which the maintenance plan may apply needs to be collected. This is often a dynamic process which starts with an asset list which was hidden in some drawer/folder, and later is periodically updated. The preparation of the inventory can also be used for a preliminary assessment of the assets in question.
- The procedures. A maintenance manual for civil assets is required. This would include the inventory, the maintenance policies, documentation requirements, inspection procedures, and some guidance on repair alternatives or preferences. It is unlikely that a cement plant will be in possession of the core skills necessary to set up this type of project from scratch as the detailed civil engineering knowledge is not normally part of a factory skillset. However, once established a well organised plant maintenance department should be more than capable of managing the program on an ongoing basis perhaps with occasional specialised assistance if required.

A proven, summarized and high-level flow chart is presented in the following diagram, which separates the main activities between the Steering Group and the Project Management team.

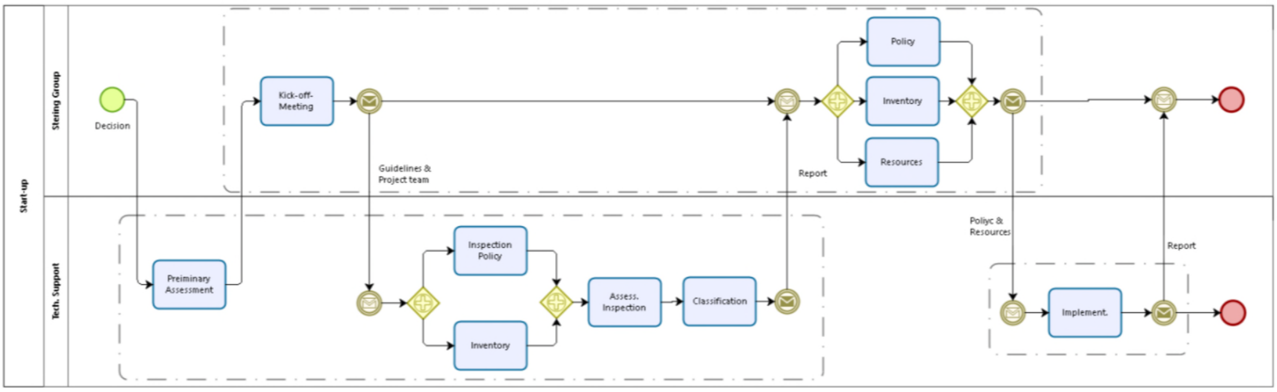

Figure 4: Simplified BPMN diagram