PAPER VERSUS PLASTIC

Catherine Kerninon, EUROSAC, and Kennert Johansson, CEPI Eurokraft, discuss the results of a recent study by Sintef which investigated the shelf life of paper and plastic cement sacks.

The European cement industry has set itself ambitious goals by announcing its intention to strive for carbon neutrality along the cement value chain by 2050. Consequently, measures to reduce emissions and environmental aspects are becoming increasingly important throughout all areas of the supply chain. This also affects the industry's packaging criteria. From the two sack solutions that are used most widely on the European market – cement paper sacks and cement plastic sacks – the paper sack is clearly the favourable option in terms of environmental impact. Its carbon footprint is 2.5 times lower than that of polyethylene cement sacks (World Cement, January 2019).

But of course, fillers do not want to compromise on the performance of their packaging in favour of a sustainable solution. They must also respond to their customer's high expectations and requirements and, at the same time, tap economic advantages. Whether filling speed, product protection, pack cost, cleanliness or shelf life – all these aspects must be considered when choosing the perfect packaging. A comprehensive study among fillers and retailers of cement and other building materials by RISE (formerly Innventia) has revealed that fillers especially profit from lower packing costs and higher filling speeds when using paper sacks (World Cement, April 2016). When it comes to shelf life, stakeholders have claimed that plastic bags provide a better shelf life than paper bags. However, there is no reliable data available. To ensure that the paper sack industry meets the requirements of cement producers also in terms of shelf life, CEPI Eurokraft and EUROSAC requested the independent Norwegian research organisation Sintef to investigate the shelf life of cement paper sacks and form-fill-seal (FFS) polyethylene cement sacks. The outcome shows: paper sacks perfectly preserve cement, even when stored for 1 ½ years. They provided equivalent protection for cement to plastic sacks when stored under the same adequate conditions. Whether total weight, level of hydration, mortar strength, initial flow behaviour or 28-day compressive strength – the quality and performance of the cement from both types of sacks was well within the requirements for the cement industry. This article will explain the design of the study and present the results in detail.

Paper sacks protect the product quality and performance for at least 18 months in storage. Image storage depot: Sika Deutschland, Rosendahl, Germany.

The sacks were stored in an outside store house in Norway. Copyright: EUROSAC/CEPI Eurokraft.

About the study

For the investigation, a standard 25 kg European cement paper valve sack made of two paper layers of 80 g and 70 g with a 12 µm perforated high density polyethylene (HDPE) free film barrier and a standard plastic sack made of three layers of COEX PE film (LDPE, HDPE and LLDPE) with a total thickness of 120 µm were used. All sacks were filled with Portland cement CEM I 52.5 R according to European standard EN 197-1 cement. Due to their smaller capacity, two plastic sacks were employed for each batch of 25 kg cement.

Although the typical storage time for bagged cement in Europe is estimated to be no longer than 2 to 3 months, the study set out to determine how the sacks perform throughout longer storage periods of up to 18 months.

Storage conditions

Stored in an outside storage house in Norway, a total of three sacks per type were tested. Representing the typical secondary packaging, the sacks were stored on a wooden pallet and covered by a plastic stretch film. The sacks were exposed to changing climatic conditions. Temperatures varied between –17.9˚C and 32.1˚C and the relative moisture ranged from 28% to 96% (sampling of humidity on a random basis).

Sampling and homogenisation

After 9, 12 and more than 18 months of storage, cement samples from both sack types were collected and analysed. The sampling and homogenisation of the cement were conducted as follows: In the first step, the cement was divided into four equal parts. Secondly, two diagonally opposed quarters were recombined and manually homogenised (mixed). Step 1 and 2 were repeated three times, resulting in sampling approximately 3 kg of cement from each sack which was sent for analysis.

Test methods to evaluate cement properties

The samples were subjected to three different test methods to determine the water content in the cement and the performance of the cement after each storage period.

Thermogravimetric analysis

In a thermogravimetric analysis, the total amount of physically and chemically bound water in the cement was measured by registering the weight of the sample as it was heated from 30˚C to 950˚C. A weight loss (loss on ignition) would indicate the formation of a hydrate product due to the release of H_2O (decomposition of hydrates) or CO_2 (decomposition of carbonates). The temperature region 50 – 350˚C corresponds to the decomposition (loss of water from hydrates) of gypsum and cement hydration phases such as calcium silicate hydrate gel, ettringite or calcium monosulfoaluminate hydrate. Mass loss in the range of 400 – 500˚C corresponds mainly to the decomposition of calcium hydroxide, while the range 600 – 950˚C corresponds to the decomposition of calcite, vaterite and aragonite, as well as complex carbonate phases like calcium hemi- and mono-carboaluminate hydrates.

After 9, 12 and more than 18 months of storage, cement samples from two diagonally opposed quarters were taken and recombined. Copyright: EUROSAC/CEPI Eurokraft.

The cement samples were manually mixed before being sent to analysis. Copyright: EUROSAC/CEPI Eurokraft.

Calorimetric analysis

Secondly, a calorimetric analysis was conducted on the cement paste mixed externally from the samples to measure the amount and rate of heat which evolved during cement hydration. Measurements were performed up to 24 hours from the point of first contact between dry powder and water against a calibrated reference of similar mass and heat capacity. As the hydration reactions proceed, heat is released. The heat production rate, which is proportional to the hydration rate of the cement, is recorded in the isothermal calorimeter.

Mortar casting

The third analysis was mortar testing, which measured the initial flow and 28 day compressive strength according to DIN EN 196. This test method indicates if the performance of cement varies or remains constant over the defined period.

Paper and plastic sacks provide equivalent shelf life

The results of the research give evidence: paper sacks and FFS polyethylene sacks grant equivalent protection to cement when stored under the same conditions for 18 months.

Total weight loss less than 0.55%

According to the thermogravimetric analysis, with increasing storage time the total weight loss (loss on ignition) for paper sacks increased slightly more than for plastic sacks. It was 3.17% for plastic sacks and 3.61% for paper sacks.

The higher weight loss mainly occurred in the 50 – 350˚C temperature interval, indicating formation of hydration products. However, this latter result is an increase of only 0.55% compared to the fresh cement and is still within the requirement of ≤5.0% loss on ignition for cements according to DIN EN 197-1.

Consistent level of hydration

The calorimetric tests showed that the levels of hydration within 24 hours were essentially unchanged. The cumulative heat of hydration after 24 hours, which correlates to the mortar strength at 24 hours, was within the standard repeatability (5 – 7 J/g) for all the tested cement samples.

Unchanged mortar strength and flow behaviour

The results of the mortar cast testing indicate a roughly 10% lower compressive strength for mortar cast of the cement samples taken from the FFS polyethylene sack after more than 18 months of storage. Since the cement in question did not show significant signs of pre-hydration by the thermogravimetric or calorimetric analysis, this observation cannot be due to pre-hydration. The lower compressive strength is due to a greater volume percentage (vol%) of entrained air. As a rule, the compressive strength is reduced by 5% for each vol% of entrained air. The weight of the cast prisms was lower for this sample, corresponding to about 2 vol% more entrained air, which explains the 10% reduction in compressive strength. Having corrected these variations in entrained air, the flow and the 28 day compressive strength for mortar cast with the cements did not change significantly after storage in both tested sacks. Adding to that, the mortar strength at 24 hours was within the standard repeatability for all the tested cement samples.

Conclusion

The outcome of the study revealed that paper sacks provide very good shelf life performance, even over a period of at least 18 months. They perfectly protect the quality and properties of the product. Cement fillers who opt for paper sacks can have the whole package: an environmentally friendly packaging that reduces CO_2e emissions along their value chain as well as a high performer in terms of shelf life. Finally, they profit from economic advantages due to high filling speeds and low packing costs. ■