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Use of fly ash from biomass power plants in mine backfill

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Abstract

Process optimisation is a recurring objective in any industry that aims to remain competitive in the market. In mining, in particular, the cost of operations defines the lifespan of the mine, making process optimisation directly impactful on extending the life of the exploitation mine.

Mine backfilling is one of the activities with the greatest economic impact in mining operations. Within the backfilling process, the binder (typically cement) represents the highest operational cost, accounting for up to 50% of the total backfilling expense. As such, there is a continuous drive to find better or more efficient binders or cement additives in order to optimise the mine backfilling process.

Traditional cement is expensive and significantly contributes to an increased carbon footprint. Supplementary cementitious materials, such as fly ash and slag, can be incorporated as a sustainable alternative to the binder mix. These materials help improve the performance of the cemented paste, reduce costs, and make the operation more environmentally friendly by revalorising industrial by-products.

The case at hand involves the incorporation of fly ash from biomass power plants as an additive to cement in mine backfilling. Fly ash is the residue obtained by electrostatic precipitation or mechanical capture of dust particles present in combustion gases from thermal power stations (whether coal-fired or biomass-based). The use of fly ash from coal-fired power stations as an additive in concrete and even in the production of certain types of cement is standardised and well-established. However, there is currently no standardisation for fly ash derived from biomass power plants.

This study presents the feasibility of using this type of fly ash as a cement additive in mine backfilling. It will enable the production of a higher-quality, longer-lasting cemented backfill, reduce operational costs, and contribute to a more stable and environmentally responsible mining operation. The decline of coal-fired power stations and the proliferation of biomass power plants make it necessary to study and work towards the revalorisation of these new residues, reaffirming the commitment to a local circular economy.

Keywords: *biomass fly ash, binder reduction, circular economy, backfill process optimisation*

1 Introduction

Sandfire MATSA currently operates 3 underground mines located in the Iberian Pyrite Belt, one of the most important metallogenic regions in the world, rich in massive sulphides and with a long mining tradition dating back to Roman times. These 3 mines are known as Aguas Teñidas Mine (ATE), Magdalena Mine (MGD), and Sotiel Mine (SOT). The minerals extracted from these mines are processed at the mineral treatment plant (PTM) located above the mineral body of the ATE where copper, zinc, and lead concentrates are produced. An overview of the mine operations are given in Figure 1.

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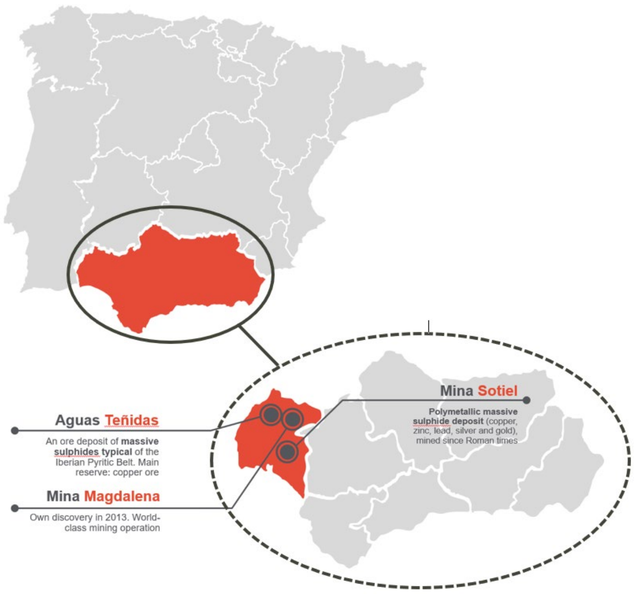


Figure 1 Mine operations in Huelva, Spain

A total of 4.7 million tonnes per annum (Mtpa) of ore is extracted, from which 0.6 Mtpa of mineral concentrate is obtained and 4.1 Mtpa of tailings are generated from the process. These tailings are managed as follows:

- 2.1 Mtpa are delivered to the tailings management facility.
- 2.0 Mtpa are feeding the paste plants at ATE and MGD, where these tailings are processed and converted into 2.8 Mtpa of paste for mine backfill, used to fill the stopes of the ATE and MGD mines.

Almost 50% of the tailings volume are used to prepare the paste recipe mix and poured out into the mine they came from. A diagram of this process is shown in Figure 2.

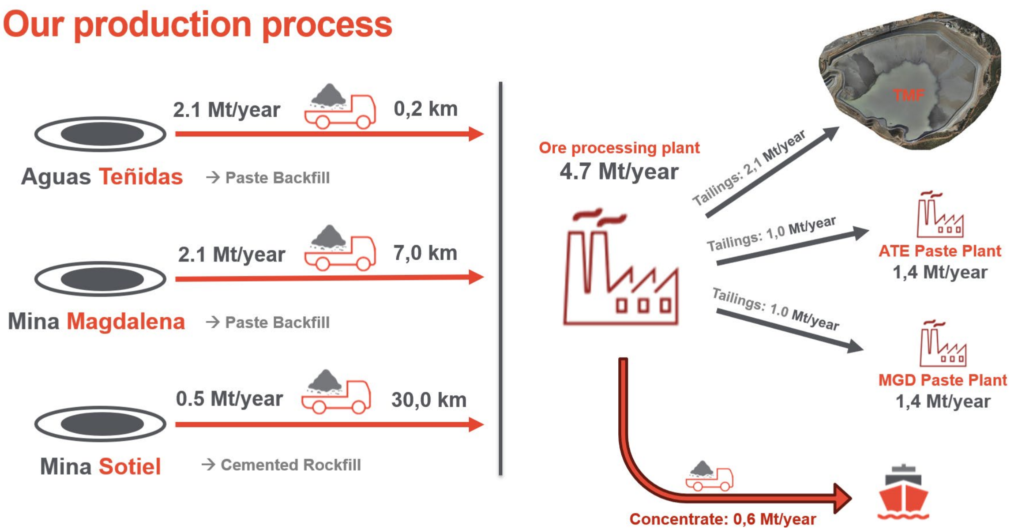


Figure 2 Process flow diagram

All mines owned by Sandfire MATSA have a cut-and-fill mining method to provide greater stability and to achieve the maximum possible recovery of the orebody.

At ATE and MGD mines, given their proximity to the mineral processing plant, cemented paste backfill (CPB) is used, which, in addition to the above benefits, results in less deposition of tailings in the tailings storage facility, providing greater optimisation of process infrastructure and a more environmentally friendly operation.

At the SOT mine, due to its distance from the mineral processing plant, the current backfilling method is cemented rockfill (CRF).

In addition, and to better understand the backfill process quality assurance program, the processing plant has 3 processing lines, aiming to ensure the most homogeneous possible ratio across the lines. To achieve this, 5 ore blendings are carried out, generating 5 different types of tailings:

- **L1:** line 1 processes copper ore (ATE cobrizo [COB] ore, ATE STW COB ore, MGD COB ore).
- **L2:** line 2 processes copper and polymetallic ore (adding SOT polimetalic [POL] ore, SOT COB ore to the previous)
- **L3:** line 3 processes polymetallic ore (ATE POL ore, MGD POL ore, CST POL ore).

All these different tailings types create variability in tailings behaviour both for transport in terms of rheology (Gamboa et al. 2026) and for backfill in terms of unconfined compressive strength (UCS) (Gamboa & Castilla 2024). Therefore, the design and operability of the downstream backfilling process must be prepared to absorb these variations.

A schematic representation of tailings management, from the deep-cone thickeners at the processing plant (where tailings are thickened to a solids concentration of 65%) to their different destinations is given in Figure 3.

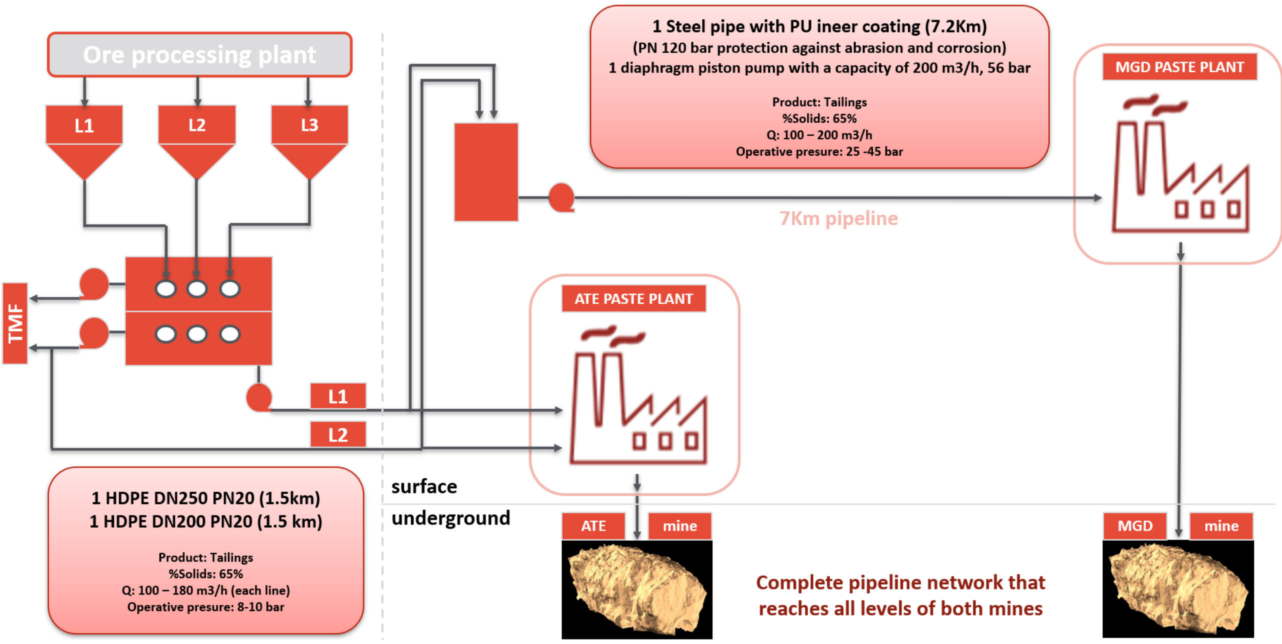


Figure 3 **Tailings management process flow diagram**

The paste plants at ATE and MGD receive almost 50% of the tailings generated at the processing plant (PTM) to produce paste backfill at a rate of up to 150 m^3/h, with a solids content of 75% (w/w).

2 Cemented paste backfill

It is widely known that cemented paste is used for mine backfilling, with the purpose of stabilising the orebody and relieving internal stresses that occur when stopes are left open without filling. Additionally, cemented paste allows for greater ore recovery because it eliminates the need for pillars as it can remain exposed vertically to enable mining of adjacent stopes and even overhead stopes once the paste has cured.

Cemented paste is an industrial product composed almost entirely of tailings from the mineral concentration process, resulting from tailings filtration. When mixed with cement and various additives, it acquires properties that allow it to be transported underground to fill voids and once cured, it provides the necessary stability to continue mining adjacent stopes, achieving maximum ore recovery. The cemented paste manufacturing process is carried out in the respective paste plants.

As described in the Introduction, there is a big variability of tailings to be handled in the paste recipe mix preparation and generally speaking, the paste recipe mix has the following composition:

- 68–72% w/wof tailings
- 2–8% binder (depending on the exposure conditions of the paste)
- 24–26% water
- Admixtures to reduce the water content while improving the flowability of the paste and pressure loss per metre.

3 Background

3.1 Additives for cement and fly ash

Calculations conducted, with the information presented so far in this document, show the significant cost of binder in the mine backfilling operation. The binder used is mainly high-performance cement to meet the necessary requirements with relatively low dosages.

The aim of the backfill department has been to find a new source to try to reduce the binder consumption, its carbon footprint and its cost at the Sandfire MATSA operations like the study presented by Safari et al. (2025).

In underground mining worldwide, the use of fly ash from coal-fired power plants as a cementing agent in paste backfill is widely known. These ashes, added to the cement commonly used in paste backfill, provide the paste with greater strength. Additionally, the ash gives the paste greater stability, being less affected by oxidation over time. Therefore, they allow a reduction of the percentage of cement used in paste backfill while improving the overall properties (Ding & Zang 2020; Wang et al. 2022)

Currently, fly ash from coal-fired power plants is used in the manufacture of some types of cement (CEM II, CEM IV, and CEM V).

4 Objectives

The main objective of this study is to produce a higher-quality paste for mine backfilling, increasing its strength and long-term durability while enabling operational improvements and system optimisation. UCS will remain constant or improved while evaluating the different paste recipe mixes and fly ash content replacing former binder dosage. Furthermore, this will result in cost reduction in paste production, achieving a more efficient operation and ensuring continuity of mining activities.

A binder reduction calculation will be conducted and given for a one-year period of backfill process time, knowing an initial investment will be required to upgrade the paste plant in order to be able to dose a portion of biomass fly ash to the paste recipe mixes.

It is not object of this study to consider the associated maintenance costs of the fly ash dosing system as the binder savings should be significantly higher than insignificant maintenance costs.

The backfill department understood there were some topics to be addresses prior to industrial scale or pilot scale testing:

- fly ash suitability for paste backfill
- fly ash sourcing volumes to meet backfill throughput
- fly ash production rate against backfill production rate (continuous operation)

- environmental permits
- fly ash transportation and storage on site.

This study and its project has gone through the respective authorisation of the Provincial Mining Authority even there is no applicable legislation with the addition of biomass fly ash, the variation of the paste recipe mix demands its respective environmental permit

5 Experience with alternatives to binder

At the time of writing this paper, Sandfire MATSA has not previously used fly ash for paste backfill due to the distance from active coal-fired power plants in Spain. However, tests have been carried out with other byproducts (or waste) from regional industries, such as copper slag from a copper smelter nearby, where the results obtained were not satisfactory and concluded that this slag would never replace cement under any circumstances. Nevertheless, in the same region, there is currently a biomass powerplant, ENCE, which has 3 units, each consisting of a biomass boiler and a steam turbine (HU-41, HU-50, and HU-46) with different capacities for producing this ash.

At the origin of this project, the fly ash produced by ENCE's biomass plants was a waste that had to be recycled, representing a significant cost for ENCE. Once the feasibility of this project was confirmed, the first step was to obtain the classification of this fly ash as an industrial byproduct for backfilling the ATE and MGD mines.

6 Project feasibility

As introduced in the objectives section of the paper, the industrial scale project needs to go through a project feasibility study answering the following open topics

6.1 Fly ash suitability for Sandfire MATSA operations

First, a series of tests have been carried out that are aimed at observing the effect that fly ash has on a predetermined cement dosage. This way, reference samples with 2, 3, and 4% of 'cement only' will be used, along with samples to which ash has been added.

Once the results of the first series are obtained, a second series will be conducted in order to establish those combined dosages of 'cement and fly ash' that are capable of replacing a 'cement-only' dosage. Finally, an attempt will be made to evaluate whether fly ash is effective for all types of tailings and to analyse the differences observed in each case.

6.2 Fly ash requirements on site

The annual cement consumption for paste backfill is approximately 130,000 t, with a cost of EUR 13 million. The purpose of this study is to explore the option of reducing cement consumption by 20% (26,000 t) and replace it with an amount of fly ash ranging from 25,000–50,000 t. This production level should be required to meet the backfill needs per year.

The fly ash production of ENCE is 12,000 t/year for HU-46 type, and 36,000 t/year of HU-50 type meeting the needs of the paste fill operation.

6.3 Daily production rate

The ash production rate is uniform, so by maintaining continuous operation of the paste backfill plants at Sandfire MATSA, a stable and continuous process can be established. 152 t/day are produced every day at ENCE's facilities.

As known worldwide, a paste backfill plant has downtime and does not run constantly every day, so the utilisation rate of the paste plants are +83% at ATE paste plant and +81% at MGD paste plant, requiring around 450 t/day as an average of binder, thus a fly ash silo needs to be sized properly in order to meet the batch paste processing circuit ensuring a continuous operation. 350–500 m^3 silos are considered to be built on the existing paste plants to be able to ensure a continuous fly ash dose when required.

6.4 Production stoppage at ENCE biomass powerplant

ENCE has an annual scheduled maintenance shutdown of the entire facility, lasting around 15 days. During this period, no ash is produced, and original paste mix recipes will be considered in order to avoid a giant silo to be built at ATE and MGD paste plants.

For the rest of the year, production is stable and may only be affected by unexpected stoppages, which typically last no more than 2–3 days. There has been no case where both plants have stopped simultaneously.

6.5 Fly ash transportation and storage

Transportation of fly ash meets the same demands as binder and trucking to mine site will be considered.

Calculations made based on regular production of 152 t/day at the powerplant and the backfill dose requirements for the fly ash lead into 350–500 t silos to be built at each paste plant.

6.6 Environmental permits and implications

Currently, fly ash is used in the production of fertilisers and soil materials, as well as historically in the manufacturing of type II, IV, and V cements. There are no environmental implications that prevent the use of fly ash in paste backfill. This would be a clear example of circular economy, where the waste from one industry becomes the raw material for another, with environmental benefits for the region.

7 Laboratory tests

As explained at Section 6, 2 series of tests have been carried out at the time of writing this paper. The first focused on observing the effect of adding fly ash to a mixture produced under predefined conditions, and the second aimed at identifying those ‘cement and fly ash’ dosages capable of replacing the reference ‘cement-only’ mixtures.

The following section details the tests performed and the results obtained.

7.1 Series 1: effects of fly ash on standard cement dosages

The solids content of the paste (% w/w) depends on its workability. Ideally, the paste would only require the amount of water necessary for cement hydration, which would yield the best strength results. However, such a paste would not be pumpable through pipelines, so a minimum slump is required to ensure it can be transported.

For daily operations, a minimum slump is set (depending on the area to be backfilled) to achieve the necessary workability. Thus, there are areas requiring a slump of 175 mm and others needing only 225 mm or more.

Therefore, to ensure result consistency and enable a meaningful comparison, all mixtures considered must have a similar slump by setting a uniform solids percentage across all samples.

Additionally, to guarantee comparability, the following criteria have been established:

- Paste samples are taken on the same day for all dosages.
- All dosages are prepared on the same day.

Table 1 presents the results obtained.

Table 1 Effects of fly ash on standard cement dosages on 1 July 2020

Sample	Cement (%)	Fly ash (%)	Slump (inch)	Density (t/m³)	UCS (kPa) 7 days	UCS (kPa) 14 days	UCS (kPa) 28 days	UCS (kPa) 56 days	Binder (%)
A	4.0	0.0	6.5	2.25	424	429.5	354	302	4.0
B	4.0	1.5	6.3	2.22	650	606.5	485	646.5	5.5
C	4.0	3.0	6.5	2.19	690	920.5	843	980.5	7.0
D	3.0	0.0	7.0	2.23	341	284.5	244.5	267	3.0
E	3.0	2.0	7.0	2.21	526	549	494	468.5	5.0
F	3.0	4.0	6.0	2.20	588.5	888	934.5	893	7.0
G	2.0	0.0	6.7	2.21	286	251	174	107	2.0
H	2.0	2.5	7.3	2.21	290	351	426.5	299	4.5
I	2.0	5.0	8.3	2.20	256.5	241	253	211	7.0

UCS = unconfined compressive strength

The values at 28 days are shown in Figure 4:

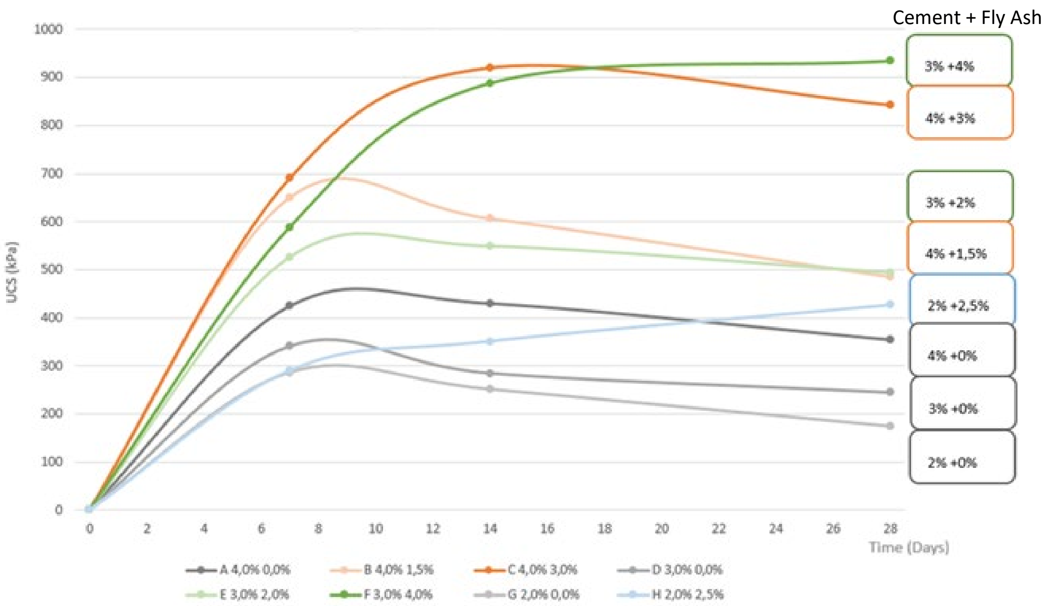


Figure 4 Evolution of unconfined compressive strength over time for the different tested samples (28 days)

Based on the 28-day results, the following observations can be found:

- It can be observed that at 28 days, the UCS is gradually increased proportionally with the binder concentration increase (e.g. for 2.0% binder the lowest UCS is achieved while for 7% binder the greatest UCS is achieved)
- The 'cement-only' samples (A, D, G) reach their maximum strength around days 8–10 and then the UCS decreases.
- The 'cement and fly ash' samples achieve higher strengths than the 'cement-only' samples, considering that:
  - Those with more cement than ash (B, C, E) also show a UCS reduction similar to the 'cement-only' samples, although over a longer period.

- ○ Those with more ash than cement (F, H) have not yet shown a UCS reduction at 28 days and take longer to reach their maximum values.
- All samples taken are homogeneous with a low range modification of solid concentration (% w/w), minimum concentration is 74.2% at sample C and maximum solid concentration is 75.7% at sample A. Solid concentration minimum variations don't have representative results on the 28 day UCS tests.

The values at 56 days are shown in Figure 5.

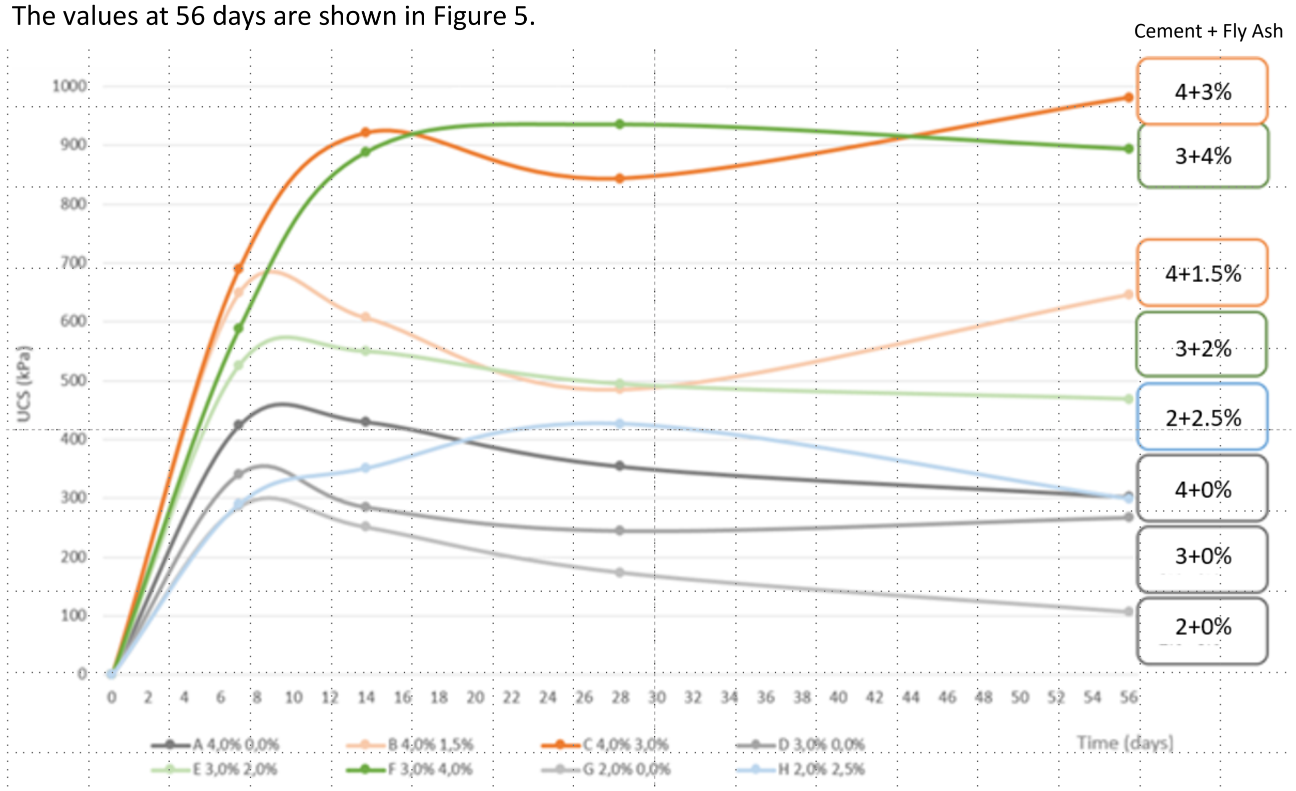


Figure 5 Evolution of unconfined compressive strength over time for the different tested samples (56 days)

Based on the 56-day results, the following observations can be found:

- Samples remain ordered according to the amount of cementing agent, confirming that the addition of fly ash increases paste strength.
- The 'cement-only' samples (A, D, G) reach lower strengths compared to those containing ash; however, by 56 days, their trends to stabilise.
- The 'cement and fly ash' samples achieve higher strengths than the 'cement-only' samples, with the following distinctions:
  - ○ Those with more cement than ash (B, C, E) regain strength after 28 days.
  - ○ Those with more ash than cement (F, H) start to slightly reduce their UCS at 56 days. Their evolution appears similar to the previous group but slower, stabilising at those values.

It is worth noting that sample E (3 and 2%) consistently remains above sample A (4 and 0%), confirming that 1% of cement can be safely replaced by 2% of fly ash. In other words, in this case, 25% of the cementing agent in the reference sample without ash can be substituted by 50% fly ash.

Additionally, samples C (4 and 3%) and F (3 and 4%) show surprisingly positive results and should be considered for replacing dosages of up to 6% of 'cement only'. A 6% 'cement-only' comparison could be given if a sample had been taken the same day the series of tests had been conducted, but variability of the tailings don’t allow the backfill department to do a strict comparison if samples are not taken same day which is one of the premises given to evaluate this results.

Finally, sample H (2 and 2.5%), despite having a much slower strength gain, ends up at 28 days with values above sample A (4% and 0%). This can also be considered for backfills that do not require immediate exposure, provided that the long-term evolution remains favourable after 56 days. This is important for the operation of both paste plants, as these premises are always taken into account when optimising the paste recipe for each stope to be filled.

The results obtained from this first series of tests clearly demonstrate the high effectiveness of fly ash in this case, being similar to the effect of cement. The goal is not to completely replace cement but to identify ‘cement and fly ash’ dosages capable of substituting the currently established ‘cement-only’ mixtures for backfill.

Additionally, fly ash at low cement dosages reacts more slowly but eventually reaches higher UCS values and provides greater long-term stability to the paste. Following these promising results, a second series of tests is launched, aimed at obtaining the standard strength values of the current cement dosages (2, 2.5, 3.5, 4, 4.5, 8%) and identifying those ‘cement and fly ash’ combinations that could potentially replace them.

7.2 Series 2: search for the cement/ash matrix over different time periods

This second series is aimed at identifying the ‘cement and fly ash’ dosages capable of replacing an established ‘cement-only’ dosage.

For the tests, the matrix shown in Figure 6 is used. Since there is not enough time to test all cases, the initial criteria are kept fixed (paste sample taken on the same day and tests performed on the same day) to ensure comparability. A small, representative portion of the matrix is tested in order to extrapolate the results and complete the matrix.

Below, the full matrix with the dosages to be tested is presented in Figure 6. The testing procedure is identical to that of the first series.

	CEMENT DOSAGES %																
FLY ASH DOSAGES %	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
0.0					X	X		X	X	X							X
0.5																	
1.0																	
1.5				X			X										
2.0			X		X	X		X					X				
2.5																	
3.0				X		X			X								
3.5																	
4.0			X		X		X				X		X				
4.5																	
5.0				X		X				X							

Figure 6 Dosage plan to be tested in order to obtain a cement/fly ash matrix

The dosages marked with an X will be tested and extrapolated to the rest of the matrix in order to obtain ‘iso-resistance’ lines for a given time period. In other words, the goal is to determine which dosages are equivalent for a fixed time period. An example is shown in Figure 7.

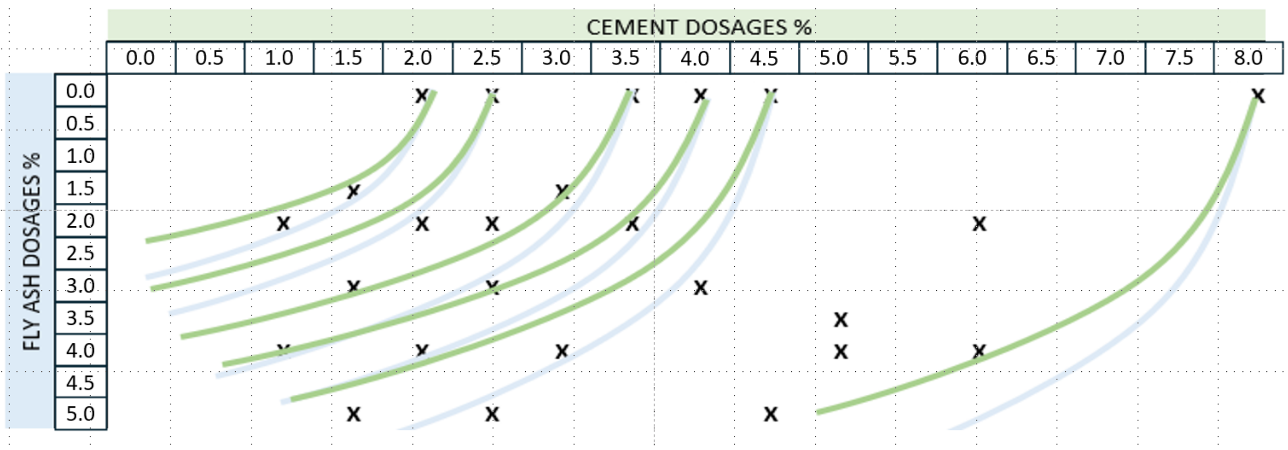


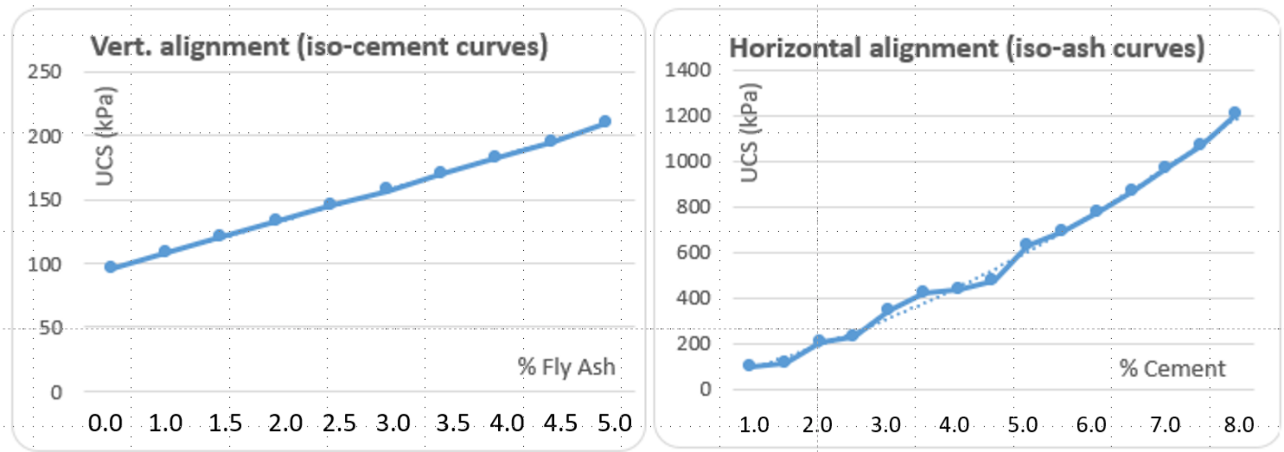
Figure 7 Example lines of equivalent unconfined compressive strength values results

For example, in Figure 7, a blue line represents a short time period (e.g. 7 days), while a green line shows the trend followed by the curves when curing times are longer (e.g. 28 days). Samples with higher ash content improve compared to those containing only cement.

Below are the results obtained from the 7-day UCS tests and their extrapolation to complete the matrix.

7.2.1 Unconfined compressive strength results at 7 days

The results obtained in Figure 7 are plotted and using the trends of the alignment curves – both vertical and horizontal – the remaining values are calculated. This process yields the following result matrix presented in Figure 8.



	0.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
0.0		96	113	203	231	343	423	433	475	625	690	775	870	965	1070	1206
1.0		108	131	221	246	357	429	461	500	655	720	810	905	1005	1110	1255
1.5		120	149	239	261	371	437	489	526	686	751	846	941	1046	1151	1301
2.0		133	167	259	276	385	445	517	553	718	783	880	975	1085	1190	1345
2.5		145	186	278	293	399	453	545	581	751	816	921	1016	1131	1236	1396
3.0		157	204	297	312	413	462	573	610	785	850	960	1055	1175	1280	1445
3.5		170	223	316	332	427	471	601	640	820	885	1000	1095	1220	1325	1495
4.0		183	242	335	350	441	482	629	671	865	930	1031	1126	1256	1361	1536
4.5		195	261	355	370	455	494	657	703	898	963	1093	1188	1323	1428	1608
5.0		210	280	377	393	469	507	685	735	935	1000	1135	1230	1370	1475	1660

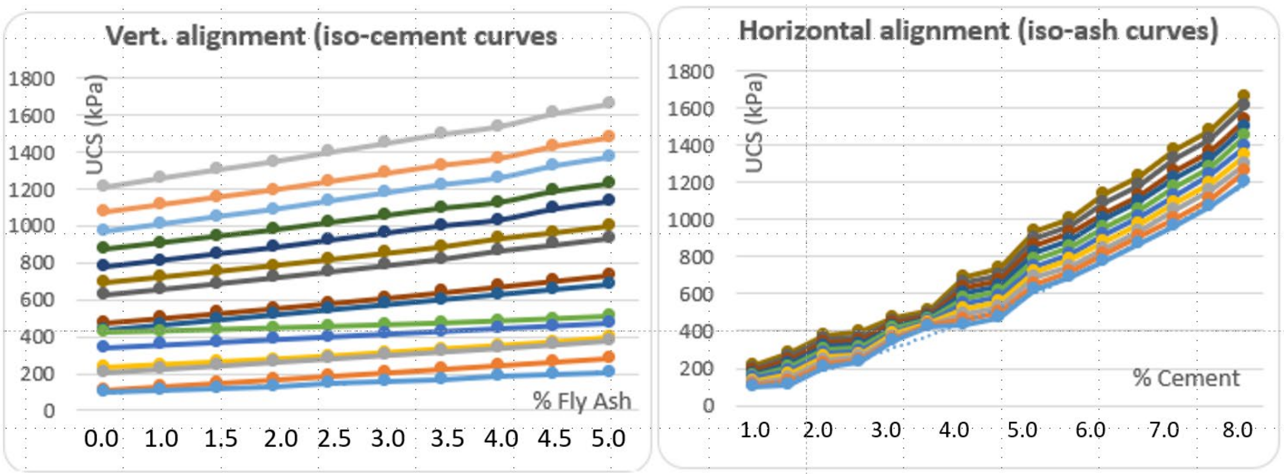


Figure 8 Unconfined compressive strength (UCS) matrix results at 7 days

In the vertical alignment graph, the values of the matrix have been provided, considering that each set of values belong to each column matrix (0–8% cement) with different fly ash dosages.

In the horizontal alignment graph, the values of the matrix have been provided, considering that each set of values belong to each row matrix (0–5% fly ash) with different cement dosages.

As can be observed in this first 7-day UCS test:

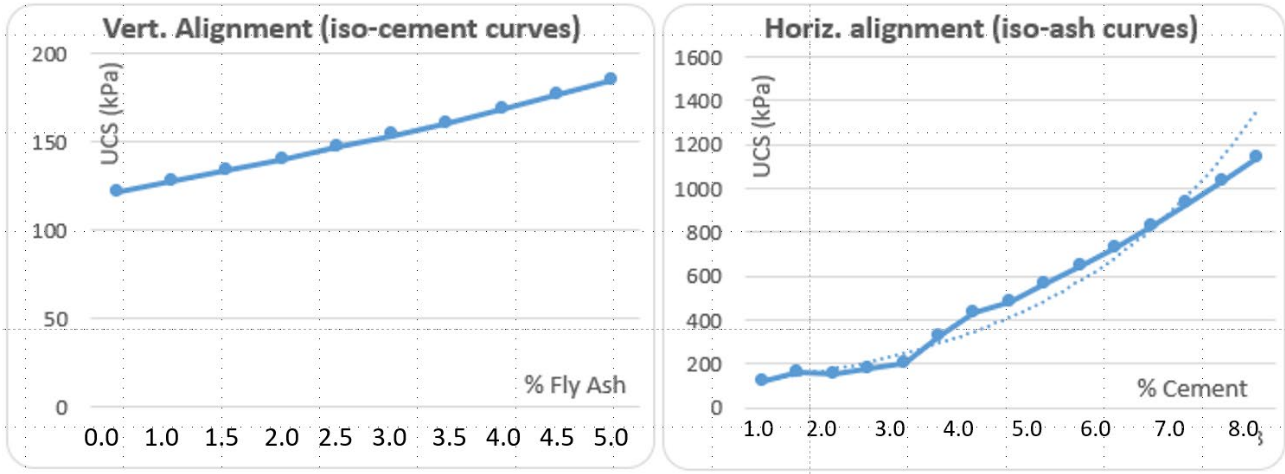
- At low cement concentrations, 1% cement can be replaced by 5% fly ash. At first glance, this may not seem like a good result; however, it is known that 'cement and fly ash' samples tend to develop strength more slowly than 'cement-only' samples. Therefore, it is expected that in the 14-day and 28-day tests, the 'cement and fly ash' samples will achieve higher strengths, while the 'cement-only' samples will show reduced UCS, making these curves more horizontal until eventually 1% cement could be replaced by 2% ash or less.
- On the other hand, at high cement concentrations, more significant data is already obtained: 3.5% fly ash is needed to replace 1% cement, or even 1.5% cement can be replaced by 5% fly ash.

At 7 days curing, the influence of cement is greater than that of fly ash.

The results are promising at first glance because the expected improvement trend delayed over the time is better in those samples containing ash rather than those which only contain cement.

7.2.2 Unconfined compressive strength results at 14 days

Figure 9 shows the results for the 14 day samples.



	0.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
0.0		122	160	154	177	200	328	430	478	564	647	730	830	930	1034	1139
1.0		128	176	190	220	251	370	480	528	614	712	810	910	1010	1114	1219
1.5		134	192	225	266	303	418	530	578	664	777	890	990	1090	1194	1299
2.0		140	208	263	310	357	470	580	628	714	842	970	1070	1170	1274	1379
2.5		147	224	303	353	412	520	630	678	764	901	1039	1139	1240	1349	1459
3.0		154	240	345	398	468	570	680	728	814	956	1099	1204	1310	1424	1539
3.5		161	256	388	438	525	620	730	778	864	1006	1149	1264	1380	1499	1619
4.0		169	272	434	478	584	670	780	828	914	1056	1199	1324	1450	1574	1699
4.5		177	288	477	518	643	720	830	878	964	1106	1249	1379	1510	1644	1779
5.0		185	324	518	560	699	770	880	920	1014	1156	1299	1434	1570	1714	1859

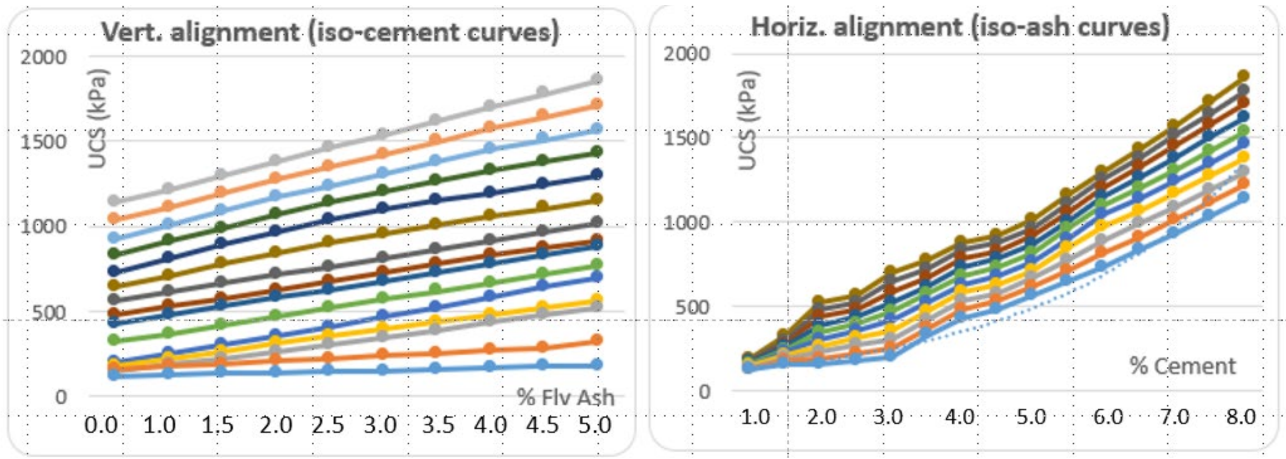


Figure 9 Unconfined compressive strength matrix results at 14 days

The trend of these 'iso-resistance' curves at 14 days is much more horizontal than at 7 days, highlighting that fly ash improves properties over time and that its effect is more noticeable at higher cement concentrations. These results reinforce the conclusion drawn in the previous series where a 25% cementitious agent can be replaced by a 50% fly ash dose being conservative at 28 days.

7.2.3 Unconfined compressive strength results at 28 days

The 28-day results continue to confirm the following expectations:

- As time passes, the ‘arrow on the table’ becomes more horizontal.
- The effectiveness of fly ash is greater at high cement concentrations.

The UCS tests at 28 could not been conducted at lower concentrations as the test campaign was really extensive and ran out of simples to be tested. Further tests have been started but cannot be presented at the time of writing the paper. In any case, from previous tests at 7-days and 14-days, it is expected that the trend will follow that shown in Figure 10. Assumptions made on the values trend have always been considered the most restrictive case or worst case scenario.

	0.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
0.0										495	595	695	795	895	995	**1133**
1.0										595	695	816	895	995	1114	1233
1.5										695	795	896	995	1095	1214	1333
2.0										795	895	**976**	1095	1195	1314	1433
2.5										895	995	1076	1195	1295	1414	1533
3.0										995	1095	1176	1295	1395	1514	1633
3.5										1095	1195	1276	1395	1495	1614	1733
4.0										**1195**	1295	**1401**	1495	1595	1714	1833
4.5										1295	1395	1501	1595	1695	1814	1933
5.0									**1286**	1345	1495	1601	1695	1795	1914	2033

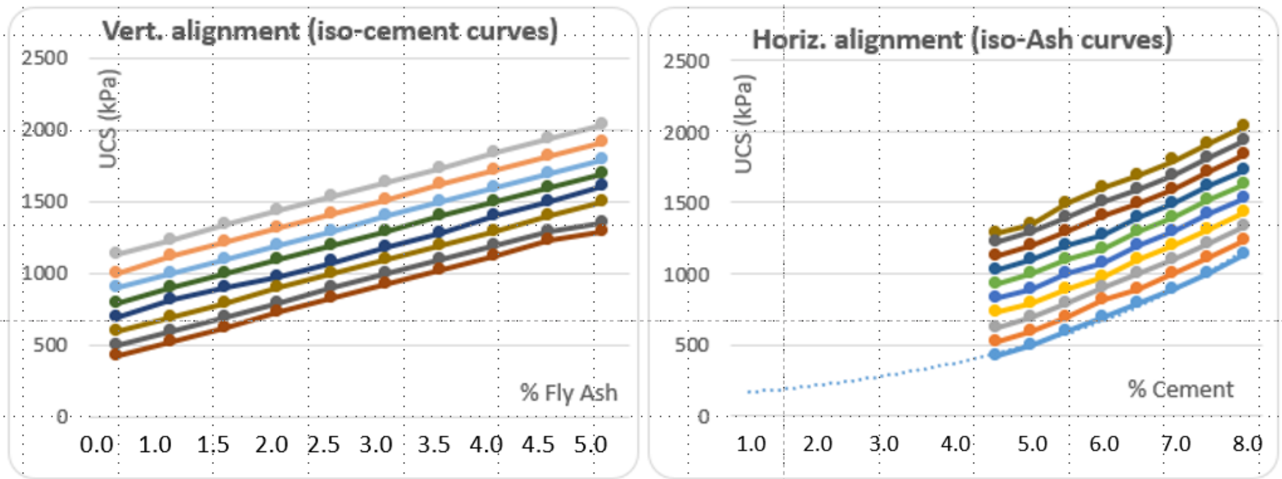


Figure 10 Unconfined compressive strength matrix results at 28 days without lower binder concentrations

8 Conclusion

Based on the findings of this case study, the following conclusions have been reached:

- Fly ash production rate from biomass powerplant, transportation, storage and dosage is feasible while meeting the production requirements of ATE and MGD paste plants.
- 350–500 t silos will need to be added to the current ATE and MGD paste plants.

From testing series campaign 1, the following findings are given:

- Indeed, fly ash from biomass power plants can partially or fully replace cement without compromising the properties of the paste compared to the reference mix without fly ash.
- Paste containing fly ash evolves more stably over time. In other words, oxidation occurs more slowly than in paste made exclusively with cement.

From testing series campaign 2, the following findings are given:

- Fly ash develops strength more slowly over time, so this must be considered when calculating the required setting times for paste exposure.
- The addition of fly ash is more effective when the sample contains higher cement content.

As per the current cement cost for Sandfire MATSA operations, an estimated reduction of 20% in current cement dosages replaced by a 40% fly ash, this would reduce cement consumption costs by approximately EUR 2.5 million, while the cost of fly ash is EUR 0.5 million. Therefore, the potential savings from implementing this project amount to EUR 2 million (minus costs related to operation, maintenance, and quality control), which are minor costs in comparison with the savings achieved.

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