Portable, Modular and Custom Built Backfill Plants—Choosing the Right Plant

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ABSTRACT

There are many ways to design and construct a backfill plant for cemented hydraulic fill (CHF), cemented rock or aggregate fill (CRF/CAF) or cemented paste fill (CPF). Backfill plants can be simple, mobile plants that require little in the way of permanent fixed infrastructure. Prefabricated modular plants are also an option and can allow clients to reduce construction costs by performing the majority of the construction and assembly work in a fabrication shop rather than on site. Lastly, custom plants, constructed at the minesite can be designed around competitively-bid equipment, with the optimum layout for operation and maintenance without any limitations due to transportation size restrictions or equipment dimensions.

The three backfill plant options listed previously (mobile, modular and custom), and a variety of hybrid options that mix the characteristics of the three, are not always well understood and the risks, advantages and disadvantages of the various options can be overlooked when selecting a plant option that is right for a particular site. This paper seeks to identify the various options available for backfill plant design and discusses the pros and cons of the options. The intent is that this paper will help mine operators understand their options better, match their approach with their environment, and avoid unintended consequences when selecting a backfill plant type.

INTRODUCTION

Many original backfill plants began as an extension to a mill facility or bolted-on to other surface infrastructure. As mine project capital gets squeezed, alternative designs that break away from the traditional custom-designed model have been used with some success. With the lure of saving capital, the low-cost options are gaining favour, but rather than painting with a broad brush, the authors hope to shed light on the different applications and encourage using the right tool for the job.

MOBILE PLANTS

The concrete industry has developed a number of different mobile plant designs for the purposes of mixing and pumping concrete. Typically, these mobile plants are used where small amounts of concrete are needed and the quality control requirements are not as stringent as in some high performance concrete applications. Out of convenience, these portable concrete systems have been adapted and used to make paste backfill for specific projects.

A major difference between mobile backfill plants and fixed plants is that the mobile plant typically does not have a tailings dewatering circuit and therefore relies on the excavation of quarried materials

(sand or previously deposited tailings). The lack of ability to use fresh tailings from a mill is a significant downside for mobile plants and restricts their usage to applications where a source of suitable semi-dry material is available.

These mobile plants can be repurposed to be used to produce paste backfill with some minor modifications. The advantages and disadvantages of this sort of system are described below:

Advantages

- No capital cost (rental of equipment) for short term usage.
- Small capital cost for longer term usage (purchase price approximately $500,000).
- Able to move to various locations without extensive mobilisation time or cost.

Disadvantages

- Requires dry feed materials (sand, dewatered tailings) and has a limited capability to handle sticky material.
- Limited capacities for off the shelf units (up to 85 m3/hr).
- Slump control and ability to fully shear mix the paste is not as good as larger, purpose built plants.
- Functioning in wet or cold climates is not easy and additional heating, covering is required.
- Operational costs are generally much high due to the lower degree of automation.

Figure 1. Mobile plant

In general, mobile plants have been seen to fill short term needs for small filling requirements very well. However, when the fill requirements become greater, the higher operating costs of mobile plants make this option less attractive. As a rule of thumb, a filling requirement of less than 200,000 m3 in a warm climate (or in the summer months of a cold climate) would be a good application for a mobile plant. A short underground distribution system that is less than 1km long is also a good indicator that a mobile plant may be useful since the impact of fluctuations in paste viscosity on pipeline friction factors is less important with a shorter pipeline than with a longer pipeline.

When designing a mobile plant system, it is important to consider all the operational requirements during the design phase to ensure that there are no unintended consequences due to the lack of a typical, indoor paste plant design. For example, the impact of precipitation on the ability of the mobile plant to work is frequently overlooked and must be accommodated in the design. This can be accomplished by reducing the design utilisation of the plant so that the required filling rate can be maintained even with rain delays.

Another example of operational challenges with a mobile plant is the ability to supply the dewatered feed material with a high degree of consistency in particle size, moisture content and chemical/mineralogical composition. If tailings are being excavated from an abandoned tailings facility for example there may be a large degree of segregation present in the deposited tailings with the majority of the fine material located in the centre of the impoundment and the majority of the coarse material located at the perimeter of the impoundment. In order to achieve a consistent paste quality (both the rheology and strength), the tailings characteristics must be consistent which would require a sampling, excavation, blending and stockpiling program in order to achieve the desired consistency. When these activities are added into the design the operating cost can quickly escalate and make this type of plant less attractive.

Mobile plants are most attractive when this source of feed material is dewatered, consistent and located nearby. Reclaiming tailings from a filter cake dry stack impoundment for example would be a much more attractive option compared to reclamation of tailings from a slurry tailings impoundment.

MODULAR PLANTS

The prefabricated and/or modular plant design can cover a wide range in the degree of modularization. Some plants are almost completely modularized while other plants have components which are modular. The line between a site constructed plant and a modular plant is somewhat blurred due to the fact that site constructed plants typically contain modular components and modular plants typically have some site constructed components.

Modular plants were, again, popularized by the concrete industry due to the fact that there was a need for thousands of concrete plants that could be quickly erected near a jobsite and put into production with a minimum of effort. Due to the volume of these concrete plants and the large number of suppliers who could design and fabricate these plants, the economies of scale and degree of free market competition resulted in a very cost effective system of bins, conveyors, mixers, silos etc. that could be purchased ‘off the shelf’ from a concrete plant supplier. These units were typically delivered in ISO container sized modules that could be quickly erected on site. With the bulk of the installation performed at the factory where internal piping, wiring, equipment installation etc. was completed, the remaining construction requirements in the field were relatively minor and could be accomplished quickly.

This style of modular design was adapted to paste backfill in various parts of the world where the core components of the modular concrete plant made up the majority of the required installation. This sort of design was most prevalent in Australia where the climate was hot and dry and dewatered tailings were readily available. As with the mobile plant option, the availability of dewatered feed material and a climate that does not require extensive buildings and protection of processes from the elements resulted in an application that was quite suitable for the use of a modular plant that is similar to off the shelf concrete plant designs.

In fact, the modular design was seen to be quite effective under certain conditions and that gave the industry confidence to move towards modularization in locations and with process conditions that were different from much of the original, successful modular plant applications. The principal challenges with this evolution was that modularization was much less suitable for climates where the process had to be protected from the environment (cold climates) and where the tailings feed material was not already dewatered.

The longer mine life and extended run times associated with a mine backfill operation also tested the limits of these designs in terms of access and maintainability. This remains an ongoing challenge with these designs as the manufacturers compress the clearances and access to meet a tighter delivery dimensions.

Modularization in Cold Climates

Due to the nature of the paste backfill process (combining solids, powder and water), in a cold climate the entire circuit must be indoors and kept above 0 degrees Celsius, except for the exterior of some process equipment such as thickeners, silos or agitated tanks. All pumps, piping, mixing, filtration and other key processes must be inside a temperature controlled building. Since the size of the plant is too large to have a single module that includes the entire building and all internal equipment, modular equipment suppliers found themselves creating buildings out of smaller modules (ISO container sized) and then bolting them all together. In a warm climate without dewatering equipment this worked well but in a cold climate with dewatering equipment it was found that much of the equipment was too large to fit inside ISO container sized modules that could be sealed off and serve as a ‘building’ while still providing the access for operations and maintenance that is required in a paste plant. In the end, the modularization of this sort of plant resulted in a large number of ‘tiny rooms’ where equipment was marooned without crane access, maintenance clearances or acceptable washdown.

In some cases, the formation of a ‘building’ with modularization does not satisfy building codes and in an extreme case, a building had to be erected around the modular building in order to satisfy the building code requirements. Obviously in that case the advantages of modularization to reduce the cost and construction schedule were far overshadowed by the cost and schedule impact of designing and building an external building around the modules.

Even HVAC design can be adversely affected since the amount of ducting, heating and cooling units required to properly ventilate all areas in the plant is much more difficult in a plant composed of many small rooms. Further, the necessary surge capacity is often overlooked in the drive to compress these modules and make everything fit together. One extreme case had all buffer removed from the paste system (no tailings, cement or paste surge left) which left the operation running hand-to-mouth and unable to keep up with the slight fluctuation in flow rate encountered during start-up and shutdown for example.

Figure 2. Vacuum pump contained within a 'modular' structure which limits maintenance and operations access

Dewatering Process

With the addition of tailings dewatering to the modular plant the size of the equipment required exceeded the size of ISO container sized modules. This required large portions of the plant to be 'non-modular' for equipment such as thickeners, agitated tanks etc. For other portions of the plant, equipment could be made to fit inside of modules, however the clearances were very tight and the final configuration of the modularized plants was not conducive to operation or maintenance. In effect, modular plant designers are left with a choice between squeezing equipment into a modular design or relaxing the requirement for modular design and essentially designing a site constructed plant with a few modules within the plant.

Essentially, the majority of the dewatering equipment requires higher ceilings, concrete sloped floors to a sump, crane access and greater clearance around equipment than a modular plant will allow.

In general, the authors experience with modular plant designs is that almost all of the dewatering circuit (thickener, filters, vacuum pumps etc.) should not be part of the modular design. Other parts of the plant such as the cement silos, mixing system and individual equipment packages such as flocculant systems or compressed air system are much more amenable to a modular plant concept and can become a part of an overall 'hybrid' design.

Advantages

- For certain applications, the construction costs can be reduced by performing the majority of the construction work at the factory.
- Can work well where climate and process considerations do not make the modular design inappropriate for construction, operation and maintenance.

Disadvantages

- In cold climates the building requirements eliminate many of the modular plant advantages in reducing construction costs and schedule.
- Modular plants do not allow the same level of crane access, operator egress, and maintenance clearance as site constructed plants. For many clients the sacrifices made in maintainability would simply not be acceptable.
- Some equipment will not fit into a module and therefore no plants with a dewatering circuit are truly 100% modular.
- Some equipment is squeezed into modules even though the downside of locating the equipment in modules outweighs the advantages.
- Modular equipment frequently struggles to accommodate local building codes or standard practices resulting in frustration during construction due to re-wiring, re-piping or sometimes complete redesign and removal of modular components.
- The plant throughput may be limited by the largest allowable shipping size of the biggest piece of equipment; the physical size of the paste mixer for example could end up dictating the production rate of the plant.

CUSTOM OR SITE-BUILT PLANTS

Paste backfill plants built on site typically require the most capital, but provide the most flexibility to include the process and equipment that is most suitable for the mine's requirements. With mobile or modular plant designs the capacity, equipment type and feed material characteristics can frequently be limited. With site built plants there is really no limit.

For example, the use of plate and frame pressure filters, crushed rock addition, deep tank thickening and other fairly common process considerations can be used in a site built plant but are not practical for a modular or mobile plant.

This flexibility comes at a cost however and the capital cost of a site built paste backfill plant is typically much larger than for a mobile or modular plant.

This higher capital cost is somewhat balanced by the lower operating costs that are associated with site built plants. The process design restrictions of mobile and modular plants are not present in a site built plant and therefore a process design can be selected that will lower operating costs and provide a more favourable NPV for the project. For example, the cost of a site built plant may be double the cost of a modular plant. However, if the site built plant process design is such that the cement content can be lowered to the point where the operating costs are substantially less than a modular plant then the payback period for the lower capital cost may be very low.

The improvement in operating costs with site built plants depends on the individual circumstances of the plant however it is frequently associated with a reduction in cement content. This can be due to greater process accuracies and the reduction of the fines component of the backfill with cyclones, addition of crushed rock to the backfill etc.

Figure 3. Example to show scale of a custom or site-built paste plant

In addition, site built plants will allow backfill to be produced with certain clients and conditions where modular or mobile plants simply would not be acceptable. For example, it is not possible for a large capacity pressure filter to fit into a modular plant design. There are examples where a modular paste system was installed and meant to accept pressure filtered tailings that had to meet a moisture spec for surface tailings disposal. This paste system could not handle the properties of the sticky, filtered tailings and the entire surface paste plant was eventually replaced. Another example is that some clients would not accept the housekeeping limitations and maintenance issues associated with modular or mobile plants and ended up constructing a series of outbuildings to house the equipment in a more maintenance friendly environment.

Advantages

- No limit on capacity, feed material, equipment selection/supplier or process design.
- No limit due to climate on the operability or maintainability of the plant.
- No limitations on plant layout.
- Better maintenance access to equipment (crane access, larger clearances etc.).
- Safer plant due to better crane access, clearances etc.
- Able to take advantage of modular design for certain components where it makes sense.
- Lower operating costs.
- Durability is generally higher with a purpose built plant receiving the proper maintenance.

Disadvantages

- Higher capital costs.
- Greater degree of bespoke engineering and longer project design schedule.
- May have a longer payback period making it not suitable for short projects.

CONCLUSION

All three types of plants have their place in the world of backfill. Mobile plants are suitable for smaller scale and temporary backfill applications. Modular plants are suitable for simple, warm climate, already dewatered feed material applications. Site built plants are suitable for the remainder of the applications.

It should be noted that there is a continuum between Modular and Site Built paste plants. Except in ideal conditions, most modular plants should have components that are custom and most site built paste plants should have some modularized components. The discussion regarding modular or site built paste plants should not be focused on one or the other, it should be focused on the degree to which the plant will be modular and site built.

Lastly, the evaluation of the appropriate plant type should be undertaken by an independent party who does not have a vested interest in the final outcome of the selection. For example, leaving the selection of a modular plant to a modular equipment Vendor will likely lead to the selection of a plant design that fits the Vendors equipment, or strategic positioning to win the contract rather than a selection that will result in the lowest NPV, or the best long term solution for the project.