

An Interdisciplinary Pilot Study and Prototype Development for the Containment of Concrete Washout Waste

Paul Holley, PhD; Eric Lynn; Benjamin Bush; and Abhay Chavan
Auburn University
Auburn, Alabama

The waste created when washing out concrete pumps and mixer chutes is harmful to the environment, yet is prevalent every day on construction jobsites across the country. The containment and disposal of this washout waste is regulated by the Environmental Protection Agency (EPA), and local authorities with jurisdiction are starting to increase policing related infractions. This pilot project was prompted by an industry need for a product that is both more efficient for the end user and also satisfies environmental concerns and regulations. Many industry professionals believe that products currently available in the marketplace are designed with little regard for the end user, presenting challenges in efficiency, safety, and regulatory compliance. To address this need, a collaborative research approach was employed between the disciplines of construction management and industrial design at Auburn University. The needs of each stakeholder in the concrete washout management process were identified in order to develop an initial concept for a better method for containment and disposal, followed by limited destructive testing to illuminate future research and development opportunities.

Key Words: concrete, washout, containment, slurry, environmental

Introduction

According to the EPA (2012), concrete washout water contains toxic metals and harmful suspended solids, including notable amounts of Chromium6, Vanadium and Barium, resulting in a pH level in excess of 12. To put this into perspective, the pH level of common household drain cleaners is often around 13.5. Washout waste is frequently generated when concrete pump trucks or mixers are washed out on construction sites; an all too common practice. If the concrete washout water is not properly contained and/or remediated, it can eventually enter bodies of water through storm drains or other means, creating a danger of high alkaline water percolating to the groundwater table. Even though federal regulations on concrete washout were promulgated in the 1990s, there has historically been little policing of the policy. In recent years, however, an increasing number of municipalities have begun enforcing regulations on concrete washout waste, motivated perhaps by environmental conscientiousness as well as revenues generated by fines. As described in Federal Code, (Title 40 – Protection of the Environment, 2009), the regulations are enforceable through State agency as well as other authorities with jurisdiction through the issuance and enforcement of permits through the National Pollutant Discharge Elimination System (NPDES).

While many contractors continue to wash out concrete pumps and mixers directly onto the soil, those that choose or are required to mitigate the risk employ management practices that range from excavating a washout pit and lining it with a plastic barrier, to contracting with a specialist for a turn-key removal service. Other approaches include various containers or collection bags; some are single-use, while others are more durable, multi-use containers. Industry response and perspective on the efficacy of these solutions is lukewarm at best, with concern over important considerations such as safety, mobility, and/or ease of use. One of the more common products utilized (when the washout is not discharged directly onto the soil) is a woven polyethylene bag. While in some ways a viable option, this particular product appears to have many design flaws that cause issues when used in real world applications. Its small opening combined with a flimsy support structure create what is essentially a moving target during the washout process, often leading to significant spillage.

This qualitative pilot study sought to use a targeted, collaborative approach in order to better understand the underlying issues as seen by a range of stakeholders. The project team consisted of a faculty member, an undergraduate student, and a graduate student from a construction management program, as well as a faculty member from the industrial design discipline at the same university. A variety of industry professionals were engaged as well, creating a combination of expertise that allowed for a unique approach to the research and design process.

The initial investigation was followed by the development and testing of a prototype. By understanding the procedures and ideologies of parties ranging from environmental agencies, to concrete pump truck operators, to general contractors; the specific needs of each could be addressed through the design. The hazardous waste produced during the concrete washout process is both fluid and heavy. The containment alone of this concrete and water mixture presents design challenges. In order to create a product that is more efficient and productive for the end user while still addressing environmental concerns, the design should consider the fundamental problems faced by each stakeholder. By defining those problems and applying this information to an iterative design process, a product prototype and multiple viable design concepts were produced specifically for the end user.

Review of Literature

A major consideration in this study was the general lack of published scholarly work related to the development of solutions for the discharge of concrete washout. There are numerous publications related to environmental impact, concrete recycling, and the use of concrete byproducts, however very little work directly related to the issue. While a challenge then to leverage existing work to further the body of research, it certainly suggests that there is an opportunity.

One such publication that directly addresses the topic of washwater and potential solutions is that of Chini & Mbwambo (1996), who describe a variety of disposal/mitigation practices including pits, reclamation units, and the use of stabilizing products and chemicals. As it relates to the current study, while this information is contextually useful, the relevant environmental regulations are very different today.

Peripherally, there are studies that support the need for regulation of water contamination. The water of the Onyi River in Nigeria became unfit for consumption after a cement plant discharged caustic water in to it. Because this is a temperate region with insufficient natural water resources, such contamination was particularly devastating (Ipeaiyeda and Obaje, 2017).

Other studies investigate the re-use of washout water to mix new concrete, in which the authors found a lack of predictability in the properties of the mixes (Su, Miao, and Liu, 2002). Similarly, Asadollahfardi et al (2015) found that concrete washout water could produce concrete mixes with desirable compressive strengths, while other studies found this caused shorter curing times and reduced workability during the finishing process (Soliman and Nehdi, 2013).

Methods

The qualitative pilot study began with a preliminary phase analyzing current processes and equipment associated with concrete washout waste on construction sites. Next, a series of interviews across a range of industry stakeholders sought to establish problems and concerns of those involved. Simultaneously, site visits and observations helped the researchers to better understand the issues at hand, and solutions currently employed. Once the problems were defined and individual needs identified, an interdisciplinary iterative prototype design commenced, followed by product simulation and destructive testing.

Preliminary Research Phase

The preliminary research served to provide a better understanding of the causes and effects of washout water containment and disposal. This began with investigating applicable environmental hazards and regulations, as well as the mechanics of concrete pump trucks, mixers, and procedures for the concrete washout process. Next, a review of current practices and products began, including the procurement and study of two products commonly used in the region. This process also included searches for current methods, available products in the marketplace, and the identification of relevant patents and prior art.

As information was gathered for the pilot study, a targeted approach to the open-ended interviews and field research was developed to ensure designs and prototypes best encompassed the industry's issues as a whole. A wide range of stakeholders with various viewpoints on concrete washout issue included regulatory agencies, environmental interest groups, general contractors, concrete contractors, and concrete pumping contractors. Additionally, an interview ideology was developed to extract information more efficiently by tailoring open-ended questioning to the interviewee's role in the washout management process. The research would focus on establishing underlying issues faced by each stakeholder in order to address these issues through design, in lieu of seeking recommendations for improvements to current products. The interviews would also look to establish each party's ideal solution to their respective washout issues, whether the solution was feasible or not. And finally, the researchers agreed the design process would be guided by worst-case conditions - a lone pump operator, in the dark, in the rain, and with one hand in dispose.

Interview Phase

After an overall project approach was established, the interview phase began. As a pilot study, interviews were conversational and based on open-ended questions based on the lack of published literature and to allow for flexibility.

Regulatory

The initial interview group provided an understanding of the harmful effects of concrete on the environment and the associated regulations. The first of this group was the Director of an environmental interest group in the Gulf Coast region. The interviewee articulated how caustic water affects a multitude of aquatic organisms and suspended solids are particularly harmful to fish gills, and gave beneficial insight into the range of regulations and enforcement policies in the region. The discussion also illuminated a recent study by the Environmental Council of the States that showed the researchers' home state provides the lowest per capita amount of environmental funding, while a neighboring state provides almost six times that amount.

Also in this interview group was a regulatory authority with a regional municipality in another neighboring state, considered fairly aggressive with their enforcement or washout water protocol. According to this engineer, fines in this municipality could exceed $2,500 per offence for repeat offenders.

Construction

Interviews in this group included representatives from four specific groups: general contractors; ready mix suppliers; providers of pumping services, and specialty waste service providers.

General contractor representatives interviewed consisted of project managers and superintendents from large scale regional and national firms. These interviews helped define basic needs of the project as seen by management personnel. Responsible for the project on a macro-scale, general contractors are often held responsible for ensuring appropriate washout procedures occur. Also, unless a specific contractor was observed violating the washout regulations, the general contractor would receive the fines and sanctions for improper waste management. Whether self-performing or not, trends were established where project superintendents desired speed over all attributes of the washout process, and project managers sought reliability and price. Multiple contractors reported that they

frequently looked to the providers of pumping services to include their own containment and clean up as part of their scope.

One self-performing company's solution for wastewater management was dependent on the scale and site size of the project. For large sites with large concrete pours, concrete washout pits lined with polyethylene are utilized, and after the accumulation of enough concrete slurry and waste, a service is hired to dispose of it off site. For this method a dedicated space for the pit needs to be available, which is problematic when the site is in an urban area. For smaller projects or for projects with constrained sites, their solution is a containment box, typically an 'off the shelf' product, often a plastic lined cardboard box that is unfortunately highly susceptible to decomposition in rain or other wet conditions.

For ready-mix suppliers, a theme emerged that site managers would ultimately prefer the supplier to handle their own chute washout internal to the truck or back at the batch plant, but the suppliers themselves indicated this was next to impossible because of the logistics of cleaning and treatment. That said, the supplier still has to wash its trucks upon return because of the remaining concrete in the drum, usually relying on silt tanks at the plant. The water passes through these tanks and it can be re-used. One supplier indicated that on site washout of the hopper and chute would normally produce up to ¼ cubic yards (CY) of concrete waste, and 10 or more gallons of washout water.

A key interviewee was the owner and CEO of a large concrete pumping company based in the Southeast. This discussion was purposefully conducted late in the interview phase in order to have enough information for questions about current procedures for buying containment products in bulk, realistic cost/benefit analysis, and marketable benefits to the concrete pumping industry. An important finding directly related to the containment issue at hand was that a pump truck can produce in excess of ¾ CY of waste and use as much as100 gallons of water during washout. From a volumetric perspective, the water could easily make up a significant portion of the contaminated components that need to be contained, and perhaps even more difficult to do so.

The final group in the interview phase was made up of parties specifically targeted to inform the design process. The first of these was with a vice president of a specialty company that provides turnkey management of washout waste. Their service is the provision of washout containers at a monthly rental fee, serviced on a cost per unit basis. The benefit of this type of service is freedom from washout management for the contractor, but concerns such as significant expense, occupation of scarce jobsite real estate, and logistics of recycling the waste did not appear to bring clarity to a solution of choice. Also interviewed was a sales representative for a large construction debris recycling company, who provided an understanding of the washout waste process after leaving the jobsite — an operation not previously considered. Both of these conversations helped to illuminate design considerations such as what types of materials or shapes would help or hurt the recycling process.

Site Observations Phase

Project site visits were considered necessary to close the gap between a conceptual understanding of the washout process and first-hand experience. These visits provided realistic information on clearances and dimensions of pumps and mixers in common field conditions such as rough terrain, confined logistics space, and proximity to resources. Notes, imagery, and video from this phase not only provided valuable perspective, but also a database that could be accessed by interdisciplinary colleagues throughout the design process. Another benefit of this phase was the discovery of additional issues with existing products and methods that had not surfaced in the interviews. By analyzing video of a pump operator's washout procedure, the design process could be further informed to address efficiency issues such as wasted movement or double work.

During the initial site observation during an elevated concrete pour, a pump operator had to essentially climb inside the container to open it completely, which was not only frustrating but time consuming. As the process continued, the efficiency of one of the two operators was substantially reduced by having to continuously readjust the container and its attachment to the truck, as the bag had no structural rigidity and had to be held in place awkwardly by thin straps attached to the underside of the concrete hopper. Upon completion, it was also apparent that containment was

only partially successful, with the operator informing the researchers that this was typical, and not the exception (Figure 1).

Further discussion with pump truck operators suggested that a wide range of simple containment devices were used, all with moderate success at best. Compounding the issues were the facts that the contained washout often needed to be moved while still wet, and that these operations frequently occurred in poor and dangerous conditions, such as before sunrise or in the rain (Figure 2).

Figure 1 - Lined bag used to attempt washout containment, an unsuccessful norm

Figure 2 - Washout in harsh conditions

The projects visited during this phase of the research ranged from a small school in a semi-rural area, to an international airport servicing a quarter million passengers per day. Across this wide range of projects, observations provided glaring examples of how site logistics, contract requirements, and regulation enforcement can impose vastly different limitations on best practices to manage concrete washout.

Design Process

Based on the research findings, interviews, and site visits, design iteration was begun to seek potential solutions and/or improvements. Numerous design features were considered, illuminating the academic and practical value of the industrial design discipline in the process. Review of the videos and images became invaluable to concept development and ideation. A broad range of solution thrusts were developed and considered, some of which were based on attributes of everyday items such as fruit or ice cube trays, while others were dynamic and more complex (Figure 3).

Concepts were categorized based on their approach to a particular solution, some as disposable single-use options, while others were more complex or costly and developed as reusable products. Some concepts were closer to the edge of available technology, while others used common products in innovative ways. Through a series of design review meetings, in combination with data from new interviews and site visits, features would be added or taken

away from the designs based on feasibility and market demand. As concepts became more practical through iterations, it became clear that the water in the washout process would be the most difficult challenge to overcome, due to the possibility of shifting or sloshing loads. Ideally, the washout water would not need to be transported or contained more than temporarily, which has significant impact on the design.

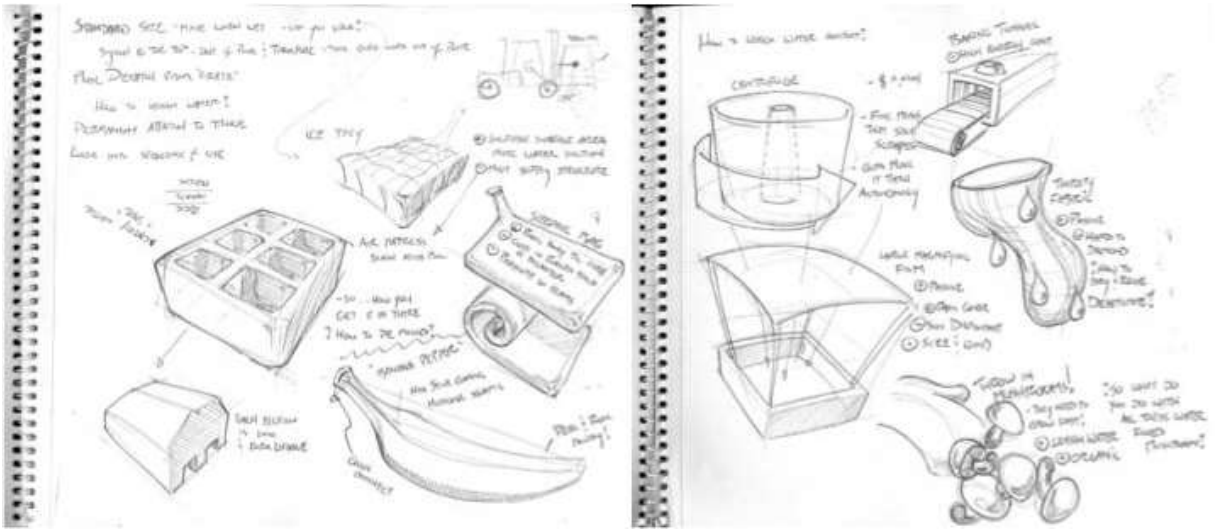

Figure 3 - Unconstrained iterative ideation – sample concepts from industrial design

Results and Conclusions

Site logistics often require a concrete pump or mixer to pull into a location where the only option after the delivery and/or placement of the concrete is for the truck or pump to vacate in reverse. If an operator is required to wash out in these situations, the ability of a container to withstand the forces of being moved while the waste is still liquid is key. Even with the range of unique and dynamic concepts, the researchers determined that an improved simple container that was easier to utilize and handle was the best solution. The challenge for this type of affordable and perhaps disposable product is mobility, as such requiring attachment points for rigging or lifting, and of a material capable of handling the significant weight of concrete and slurry. While there is a variety of current products available that are mobile, most all are rigid, heavy, and expensive.

The second major finding is the need to separate the research associated with handling the solid/slurry waste from the the disposal or removal of the contaminated water. While the concrete itself is dense and heavy, the water is in man ways more problematic to deal with. Future research opportunities are present on this front, and already being investigated. Potential thrusts could include organic substances such as tree cellulose to absorb contaminants to the point where pH levels in the washout water are at acceptable levels to be disposed of directly on the site.

The solution chosen for prototype development consisted of incremental improvement to current bag-like products, but designed much more so for ease of use and efficacy. Limited space on the trucks meant the design should be compact when stored. The opening needed to be much larger in order to catch waste coming from different openings simultaneously. The time consuming and frustrating attachment issue needed to be solved. These factors collectively resulted in a fabric basin, as shown in Figures 4 and 5.

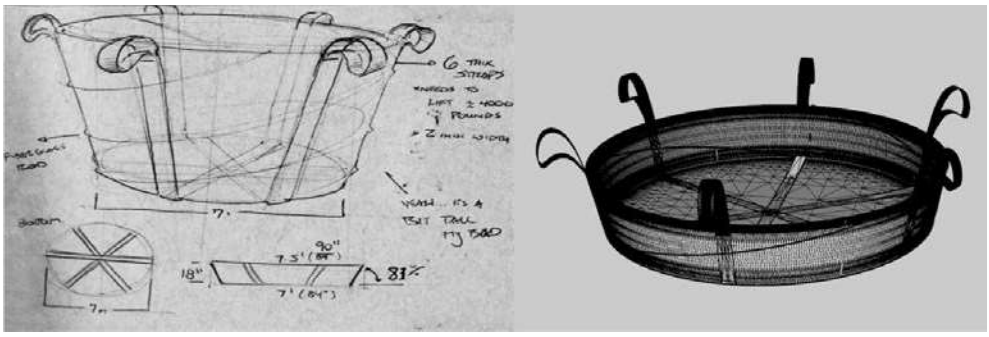

Figure 4 - Improved basin design

Figure 5 - Fabricated prototype

The container is 7 feet wide at its base and 7.5 feet wide at its opening, allowing waste to be captured from multiple openings on a concrete pump. Standing 18 inches tall, it incorporates coiled fiberglass rods to give the product structure, eliminating the need for an operator to tie up the container underneath the pump. For mobility, the concept includes webbing straps allowing the basin to be cinched and lifted. An optional skid pan made of metal or durable plastic could allow the container to slide instead of having to be lifted, protecting the container from rough terrain.

Testing

After the prototype was developed, the researchers considered alternative fabrics given the potential for weight and mobility of the concrete and contaminated water. While anecdotal, basic destructive testing was conducted with the two prototypes to get an initial sense of handling and capacity of the design (Figure 6). Gravel and water were used to simulate the handling and hoisting of ready-mix and washout water, with failure occurring at an overall load of around 1,300 lbs. While the mix was not the same density as concrete, it was useful in this pilot study to determine initial limits and design efficacy, considering the need for the basin to be mobile immediately after containment.

Figure 6 - Prototype simulated testing

Future Research

As this targeted pilot study provided real world information from multiple stakeholders about concrete washout waste management, this 'single issue' proved to be a series of complex problems - enabling the pursuit of a compelling product design. The project resulted in a deeper understanding of a growing environmental concern, and the foundation for a wide range of future research and testing. Perhaps more importantly, it provided a vehicle in which interdisciplinary academic research can yield rich solutions that might not otherwise be possible. The prototype and designs produced in this study can now be further developed and tested beyond a pilot effort, along with continued investigation into efficient and innovative ways to manage the contaminated water produced during the washout process.

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