Advantages of Mud-Jacking Grout for Use in Slab Leveling

Abstract: Settlement of concrete slabs is an ongoing problem that can be observed in all concrete slab applications including driveways, sidewalks, roadways, and interior. Removal and replacement of settled concrete slabs is costly and time consuming; as such slab leveling using under-slab lifting systems has become a popular, inexpensive, and effective manner of repairing concrete slab settlement. Slab leveling is completed by pressure injecting a flowable material underneath the concrete slab, as the flowable material fills in the space under the slab, the slab is lifted back into place. There are two main types of materials used for slab leveling: mud-jacking grouts and polyfoam leveling systems. Mud-jacking grouts are made from a combination of sand, portland cement, fly ash, and water; whereas poly-foam materials are a combination of polyols, water, and isocyanates that, when combined, expand into a foam. While both are effective at leveling slabs, mud-jacking grouts have been shown to be a more sustainable, environmentally friendly, safe, and effective solution for slab leveling. This paper presents information both mud-jacking grouts and poly-foams, as well as a discussion on the performance, recyclability, health and safety, and flammability of the materials. From the work presented herein, mud-jacking grouts are shown to be a better overall solution for slab leveling systems, particularly when the full life of the systems and environmental health and safety concerns are considered.

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Introduction

Concrete slabs are used in a variety of construction applications for structural and non-structural applications such as sidewalks, mat foundations, and pavements, among others. These slabs are typically placed on a compacted aggregate base which rests on the soil of the project site. When loads are applied to the slab, they are transferred through the slab to the aggregate base, and then the soil.

Over time, slabs can become destabilized as the soil settles due to the applied loads, lack of sufficient compaction, or groundwater erosion. When slabs are destabilized, numerous adverse events can develop such as concrete cracks, corner breaks, and excessive displacement (i.e., vertical movement). This damage results in aesthetic issues, can damage vehicles driving over them, and present trip hazards for people walking on the slabs. In the residential, commercial, and transportation construction sectors slab leveling systems are used to re-level slabs and lift the slabs back to their original vertical and horizontal positions.

When concrete slabs are damaged due to destabilization, owners and contractors have a limited set of techniques to address the destabilized slab sections. The first method of addressing the destabilization is to completely replace the concrete slab. This involves cutting or demolishing the sections of the slab that were destabilized, recompacting the aggregate and soil base, and recasting concrete slabs in place. This is often the costliest method of addressing slab destabilization, and can prevent the functional use of the slab during reconstruction. Additionally, this method results in excess waste from the disposal of the used slab and requirefor new materials to replace it.

Alternatively, owners and contractors can address destabilized slabs through repair. Repair stabilization techniques often involve drilling small cores in the concrete slab and injecting a material that will induce pressure on the soil and slab. The pressure induced from the material will fill the open voids under the slab, induce vertical movement of the slab, and allow the contractor to re-level the slab system. Two commonly used re-leveling materials are cementitious grouts and expandable polymeric foams. While these two materials are used for the same purpose, they do not necessarily behave similarly, nor do they both provide the same advantages.

This paper presents information on each of these materials based on their material constituents, structural performance, sustainability, and environmental health and safety impacts. A review of how both mud-jacking grouts and polyfoam materials are made and used is presented followed by the material properties for both types of leveling materials. A review of the sustainability of each material is then provided with a particular focus on recyclability of the materials. Finally, a review of the environmental health and safety concerns when using each material is provided, with a focus on both worker safety and public safety.

Mud-jacking Grouts

Cementitious grouts are a common material used for slab leveling and repair. The process of injecting cementitious grout is often referred to as “mud-jacking”. Mud-jacking materials are generally cementitious grouts which typically include a blend portland cement, fly ash, fine aggregate, water, chemical admixtures, and air. The actual amounts of each constituent can vary depending on the properties needed for a particular job and availability of local materials. Like standard concrete, mud-jacking grouts are generally made from materials produced and available locally and do not require significant levels of transportation to be obtained. Also, the constituents for mud-jacking grouts are widely available in most locations and are produced from abundant natural resources, which lessens the impact of the material on natural resources that may be needed elsewhere.

In many applications, the properties of the cementitious grout are characterized by its efflux time, which is a measure of the rate of flow of the grout in its fresh state, pumping pressure and the compressive strength of the grout material when it is hardened. Typical efflux times are in the range of 10-20 seconds, pumping pressures are in the range of 200 psi or lower [1]. The grout is pumped under the slabs using a pressurized line attached to core holes cut through the slab. As the grout flows under the slab it fills in open areas underneath the slab and lifts the slab into place vertically. The amount of grout pumped into place depends on the void space underneath and how much vertical lift is required to move the slab back into place. The cementitious grout will not compress as it fills in the space and maintains the same properties when delivered to the subgrade under pressure as it would if cast above ground. The mud-jacking grouts can be used in a wide range of applications, including colder temperatures.

Compressive strengths of mud-jacking grouts are typically lower than 1000 psi, and will vary depending on the amount of cement and water used in the mixture [2]. The final strength of the grout can be tailored to the requirements of each project quite easily. If a stronger material is needed, additional portland cement can be added to increase the strength and meet the project requirements. Determining the strength of the cementitious grout can be completed through simple compression tests on specimens produced from a sample of the grout used on site [3].

<u>Poly-Foam Systems</u>

Expandable polymeric foams are often made of high-density polyurethane materials. These materials consist of a series of two chemicals, namely, an organic hydroxyl blend (or polyols), and a water and isocyanate mixture. The materials are mixed together under pressure, causing an exothermic chemical reaction to occur which creates the expandable foam material. Isocyanates and polyols are both products derived from crude oil, an increasingly precious natural resource needed for many applications [1,4].

The polyfoam constituents are produced separately at manufacturing plants and then shipped to consumers. Unlike mud-jacking grouts, the raw materials for polyfoams are not widely available and must be captured from oil wells, shipped to refineries, and then shipped to the job site. This necessitates thousands of miles of transport for the materials which increases the cost and the environmental impact of the materials.

The two-component system is mixed on-site and then injected under the slabs where it fills in some of the cavity space and lifts the concrete slabs back into place. The polyfoam materials need to be kept heated to be used properly, requiring additional energy costs beyond just powering the pumping equipment. Additionally, use of the materials at external temperatures below 40 °F are not recommended [5]. This limits the working season for using polyfoam materials, and they often can't be used for emergency repairs during winter months.

The polyfoams have low compressive strengths, in the range of 50 - 100 psi, and are often characterized by their volume change and shear strength [5]. The strength of the materials in-situ is not well understood because the strength depends on the amount of compression that occurs in the foam, which cannot be measured easily once pumped into place under a slab. Unlike mud-jacking grouts, polyfoam strengths cannot be modified to fit a particular situation. The two-part system is a specific, proprietary blend of materials that produces the same product with the same properties each time. Therefore, the site conditions must be appropriate for use with the poly-foam system available, rather than being able to tailor the poly-foam to the site conditions.

Recyclability and Sustainability

Long-term impacts of our construction activities are an important consideration for any new construction or repair activities. An important aspect of this is the recyclability of the construction materials and reuse of demolition waste. Concrete recycling is a common activity and the waste material can be used for fill, road base, rip rap, and as an aggregate in new concrete. The process for recycling concrete involves demolishing the concrete on-site into large chunks, removing impurities such as steel and asphalt, and then sending the demolished material to a processing facility. At the processing facility the concrete is crushed into gravel size material that can be used for various applications. In order for the concrete to be recycled in a cost effective and efficient manner, the impurities attached to the concrete must be easily removed [6].

The grouts used in mud-jacking are cementitious grouts and are not considered an impurity in the recycling process. The grouts can be crushed into aggregates and used in the same applications as the recycled concrete. No special cleaning or removal is needed to recycle slabs that have been lifted with mud-jacking grouts, making their recycling cost effective and efficient [6].

Conversely, the use of polyfoam materials as a leveling system restricts the recyclability of concrete slabs. Polyfoam must be completely removed before a concrete slab can be recycled, which can be quite difficult as it sticks to the bottom of the slab where it connects with the slab to lift it into place. The polyfoam materials are organic and weak, and so will compress or break apart when used in fill or as an aggregate. Additional equipment and manpower is required on site to remove the polyfoam from the concrete slab, increasing the cost of recycling the slabs. The cost increase associated with cleaning out the polyfoam makes it much more likely that a slab lifted with polyfoam will be landfilled, rather than recycled.

The other aspect of sustainability that must be considered when comparing the sustainability of mud-jacking grouts and polyfoam is the provenance of the raw materials. As noted earlier, mud-jacking grouts are made from portland cement and natural sand mixed with water. The raw materials needed for this are abundant and available worldwide, meaning the mixture components for mud-jacking grout are not being consumed from a precious resource that is needed for other activities [1,2]. Alternatively, poly-foam is made from crude oil, which is a dwindling resource that is needed for energy, plastics, medical equipment, and other materials for which there is no other option. Poly-foam also requires substantially more transportation in the creation process, resulting in additional output of CO_2 and burning of fuel from the shipping of the material.

While slab lifting will extend the useful life of concrete slabs in the field, eventually they will need to be demolished and replaced. Poly-foam material is a polymer (plastic) material that does not degrade when disposed of, and unlike mud-jacking grouts, it cannot easily be recycled for use in other markets. The use of polyfoam materials will result in more landfilling of plastic waste material that will result in further environmental issues both short- and long-term. Beyond just the environmental aspect of disposing of poly-foam materials, in the northeast United States and worldwide, landfills are becoming more and more scarce, with landfilling fees continuing to increase. End-of-life options for polyfoam are minimal, with most of the material going to landfills, and the use of poly-foam will result in increased costs, both financially and environmentally, when demolition of the slabs takes place.

Environmental Health and Safety

Mudjacking grouts are made from a combination of portland cement and other cementing materials mixed with sand and water to form a flowable slurry that can be injected into the space underneath the slabs, fill the voids and lift the slab [1]. The cementing materials that can be used beyond standard portland cement include fly ash, slag, and limestone powder. These materials are all commonly used materials in grouts and concrete that we live and work in, walk on, and drive on every day.

Once mixed with sand and water, the cementing materials pose very low health risks. Prior to being mixed with water, dust from cementing materials and sand can cause inhalation hazards or get into eyes. Proper PPE equipment such N95 masks should be worn by workers, and work areas should be kept clear of civilians during the material mixing procedures [7,8]. Contact with the grout before it hardens can be abrasive to skin due to the high pH of the material, but this can be prevented through simple use of protective eye wear, long-sleeve clothing and work gloves.

After all of the components are mixed, the liquid slurry can be abrasive to skin and will have a high pH, which can cause chemical burns to skin or eyes. Protective clothing and eyewear should be worn during concrete mixing and placing to ensure the fresh mixture does not contact skin or eyes. Civilians should continue to be kept clear of the area until the slurry is pumped under the slabs [7,8]. Once the slurry is pumped under the slabs and allowed to harden, it no longer poses health risks to those around it. Hardened slurry does not off-gas nor does it leach significant levels of heavy metals into the ground, even in wet conditions [9].

Polyfoam slab levelers are made from polyurethane foams, and the exact composition can vary depending on the manufacturer of the material [5]. However, all systems share similar characteristics and fundamental chemistries. Polyurethane is made from a combination of isocyanates and polyols. The foam is produced when exothermic polymerization occurs which causes vaporization of liquids present in the mix and foam to form from the gas bubbles. These bubbles get trapped within the polymer material creating a foam. Once the system cures, these bubbles remain stable. This process results in rapid expansion [10].

Isocyanates are a group of highly reactive chemicals and are irritants to the eyes and respiratory system. Contact with skin can also cause significant inflammation. Severe asthma attacks resulting in death have been known to occur from exposure to isocyanates [11]. The use of polyfoam systems, therefore, requires extensive ventilation and protective equipment for those working near the chemicals prior to their curing. Beyond these health effects under normal operating conditions, the extreme exothermic reaction has been implicated as the cause of fires under slabs resulting in release of toxic gasses.

Flammability of Materials

Mud-jacking grouts are non-flammable and do not produce toxic gasses and are generally safe to the surrounding environment. Polyurethane foam based leveling systems, however, have experienced spontaneous combustion during and shortly after application. Most notably, a project in Vancouver, BC, Canada where slabs outside of a building were leveled with the polyfoam material. The foam material, which produces heat during the expansion process, caught fire underneath the slabs. The fire released noxious fumes that shut down the area around the slabs and blocked people from using the buildings around it for a week. The fire has resulted in multiple lawsuits and claims [12–14]. If the voids under a slab are too large, requiring additional polyfoam, the heat generated can be enough for the poly foam to catch fire. This creates a danger for the buildings near by, as well as personnel from the fumes. Compared to mud-jacking, additional under slab exploration needs to be completed at sites where polyfoam is used to ensure that the extent of open space and lifting requirements is well understood. Furthermore, the polyfoam systems can actually cause further compression of the soil underneath the slab during placement, increasing the volume needed to be filled, increasing the risk of heat generation from high levels of foam placement.

Material Weights

The density of polyfoam materials is low compared to cementitious grouts. Typically, polyfoam materials are in the range of 4 to 6 pounds per cubic foot, while a cementitious grout might be in the range of 100 to 125 pounds per cubic foot [1]. While this weight difference is significant from a numerical standpoint, it has negligible difference on the bearing capacity of the soil. The bearing capacity of sands, silts, and clays are typically in the range of 1,500 to 3,000 pounds per square foot [15]. Therefore, the placement of a 1-foot-thick fill of cementitious grout would only apply loads that represent approximately 5% of the soil's capacity. A load this small has negligible effect on the soil in terms of slab stabilization for most applications. Therefore, the weight difference between polyfoam and cementitious grouts is not impactful to the overall system when compared to actual loads placed on the slab itself.

Conclusions and Recommendations

Both mud-jacking grouts and polyfoam can lift concrete slabs and fill in the space underneath of the lifted slab. However, only mud-jacking grouts provide a system that can be tailored to specific applications, can be used in a broad array of situations, and provide a higher level of sustainability. The following main differences show that mud-jacking is a much more usable, safe, and sustainable choice for slab lifting.

1. As noted above, poly-foam materials are proprietary systems that will produce the same strength each time, meaning they cannot be altered for different situations or needs. Mud-jacking grout strength and workability can be modified to each situation by changing the amount of cement, water, and sand to meet the required performance.
2. Mud-jacking grouts are more recyclable, as the mud-jacking grout material can be crushed along-side the concrete slabs made with them and used as fill or aggregate material. Poly-foam materials, a plastic material, are not suitable for use in the recycling applications for concrete slabs, and as such must be removed before recycling. This increases the cost and energy requirements to recycle slabs lifted with polyfoam, reducing the likelihood that they will be recycled.
3. Mud-jacking grouts are a much safer material for use in the field. The grout materials do not off-gas or release toxic fumes, they are safer for workers to use, and they do not pose a risk of flammability. Polyfoams are made from toxic materials that can release noxious gasses. Additionally, the heat generated from the poly-foam's exothermic reaction has been known to result in spontaneous combustion after placement.
4. Mud-jacking grouts are a heavier than polyfoam materials; however, this weight difference is not significant in comparison to the bearing capacity of the soil.

For these reasons, mud-jacking grouts have been shown to be a much more reliable, safe, and sustainable alternative to poly-foam materials.

References

[1] P. Venapusa, Y. Zhang, D.J. White, Comparison of Pavement Slab Stabilization Using Cementitious Grout and Injected Polyurethane Foam, J. Perform. Constr. Facil. 30 (2016).

[2] P.K. Mehta, P.J. Monteiro, Concrete microstructure, properties and materials, 2017.

[3] A. International, C39/C39-18 Standard test method for compressive strength of cylindrical concrete specimens, (2019).

[4] W. Brewer Jr., C. Hayes, S. Sawyer, Uretek Construction Report, Oklahoma City, OK, 1994.

[5] S.P. Incorporated, Eco-Rise Technical Data Sheet, (2021). http://specialty-products.com/wp-content/uploads/2019/07/ECO-RISE.pdf (accessed May 5, 2021).

[6] A.C. 555, ACI PRC-555-01 Removal and Reuse of Hardened Concrete, Farmington Hill, MI, 2001.

[7] OSHA, OSHA Pocket Guide: Worker Safety Series: Concrete Manufacturing, 2004.

[8] Portland Cement Association, Working Safely with Concrete, (n.d.).

[9] S. Garber, R. Rasmussen, D. Harrington, Guide to Cement-Based Integrated Pavement Solutions, 2011.

[10] L. Yu, R. Wang, R. Skirrow, The Application of Polyurethane Grout in Roadway Settlement

Issues, in: Geo Montr. 2013, 2013.
[11] National Institute for Occupational Safety and Health (NIOSH), Isocyanates, (2014). https://www.cdc.gov/niosh/topics/isocyanates/default.html (accessed May 10, 2021).
[12] J. Proctor, 10 Lawsuits filed over 2010 Vancouver chemical fire, CBC News. (n.d.).
[13] CBC News, Chemical Spill Ties up Vancouver Traffic, (n.d.).
[14] T.S.C. of B. Columbia, True North Concrete Lifting LTD. vs Hydraulic Mudpumps, Inc. et al., 2012.
[15] International Code Council, 2015 International Building Code, International Code Council, 2015.