The Development and Evaluation of a New Trench Safety Equipment

Joshua D. Clesi
California Polytechnic State University, San Luis Obispo
San Luis Obispo, CA

One of the most dangerous works in construction is trench work and excavation. Fatalities that range from permanent injuries to death happen to construction workers every day, not having a lot of alternatives to prevent unfortunate incidents such as cave-ins and shoring failures. What this paper is proposing is a new invention that may solve this ongoing problem with trench safety. The idea is a crane-like lift attached to the back of a pick-up truck that will vertically lift people out of the trenches in a matter of seconds before shoring collapses or the trench caves in. This project primarily focuses on the conceptual description of this piece of machinery, along with an interview process of study that'll get insight from six safety managers and other safety personnel, with years of safety experience from construction companies like DPR Construction, Pankow, Hensel Phelps, Granite Construction, and PCL Construction on what they think about this piece of machinery discussing positive aspects, ideas for improvement, and possibilities of future research on this product. After this process is complete, the final conceptual model and design will be developed, leading to the next stages of making this a new and revolutionary device that'll save lives.

Key Words: Invention, Trench/Excavation, Cave-Ins, Conceptual, Safety Personnel

Introduction

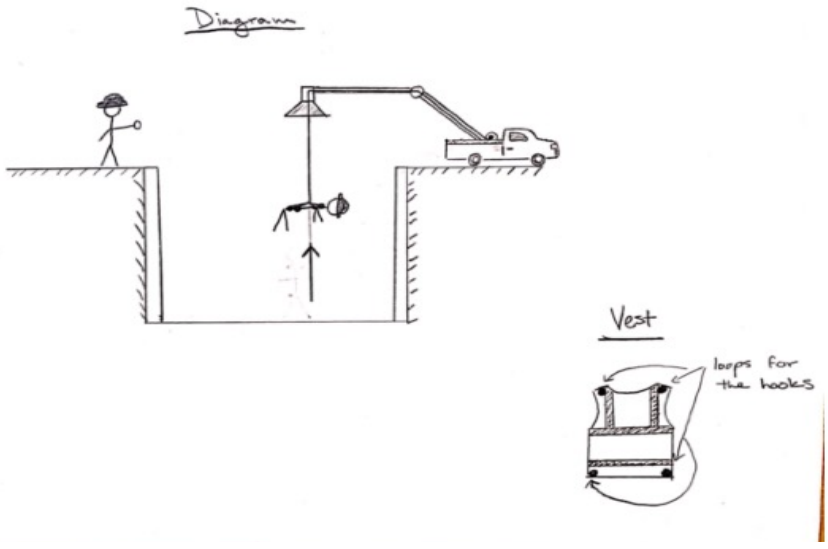
In the construction industry, there is a constant battle of making sure that hard-working laborers make it home safely to their families every single day. Construction alone is considered one of the most dangerous and life-threatening jobs to work due to numerous elements that comprise within this particular field that can harm, injury, and worst of all, kill people. In Jimmie Hinze, Xinyu Huang, and Lani Terry's article, "The Nature of Struck-by Accidents", they commenced their own study of jobsite accidents, developing a chart stating, "struck-by accidents comprised 22% of the construction fatalities. The remaining 78% were comprised of falls (33%), caught-in/between (18%), electrical shock (17%), and other (10%) (U.S. Dept of Labor)". They continue to add more into this study by including the fatality rate of all of these types of accidents by claiming, "Of the 743 cases examined, 675 accidents or 90.8% involved fatalities. The number of victims per accident ranged from one to nine persons. Of the fatality accidents, 1% had five or more victims, 3% of the cases had three or four victims, and 11% had two victims. The majority of the cases, comprising 84% of the sample, had one victim." (ASCE Library) It's in plain sight that the construction industry does indeed still have a lot of room for improvement in all categories of construction safety.

The primary focus will be established under the concept of trench safety, which has had limited course of action when it comes to safety and safety protocols. Topics as simple as having competent personnel present at all times outside of the trench, sloping and benching the sides of the excavations, placing a shield between the sides of the excavation and work areas, and having a system where ladders need to be 25 feet minimum by each person in an event of shoring failure or cave-ins still aren't protecting humans from serious injury and death. According to the article, "Mobile Point Cloud Assessment for Trench Safety Audits", they state, "Fatalities resulting from cave-in hazards during excavation work in the United States account for 48% of the trench fatalities in construction every year per Occupational Safety and Health Administration (OSHA) data. Recent trends indicate that fatalities from trench and excavation hazards in the US are increasing". Not only is this already a concern that has been an issue for countless years, but is also starting to gradually grow with years to come. It's important that this topic of concern is taken note of before things start to get worse.

With that being said, an idea was developed about a potential piece of machinery that could potentially revolutionize the construction industry in many ways possible along the lines of trench safety and safety in general. The initial

primary layout of what this idea breaks down is the concept of an attachment in the back of a pickup truck, similar to that of a tow truck, that will extend out with a boom and stick over a trench. There will be a strong cable wire that would be fed through the boom and the stick, eventually dropping down into the trench where all of the people inside of the trench working on various parts of the project. The item that would be in the bed as well within the body of the launcher will be an automatic retractable dolly system that would pull the wire in. The end of the wire that will go into the trench will then separate into four smaller cables with hooks that would attach onto the vest of the person/people inside of the trench. The four points that the hooks will connect to on the vest of the individual(s) will be two on the back part of the shoulders and two on the hips near the lower back. With all of these notified parts properly connected, secured and placed, the trench launcher will safely lift the individual up from the ground vertically, preventing them from being crushed by dirt and rubble in an event of shoring failure or a cave-in. On top of these basic parts of this product, there's a few other miscellaneous attachments that can be applied to the trench launcher. One item that can make a significant difference is the idea of a potential two-way button system that can be held by the individual inside of the trench and the competent person that would be around the outside of the trench looking over the safety of the people. This concept is believed to be one of the most crucial parts of the whole idea. With so many background noises that would being projecting around the jobsite such as heavy machinery being used, traffic from cars passing, etc. having the extra pair of eyes and ears from the competent person outside of the trench surely maximizes efficiency and a higher success rate of saved lives. The other possible attachment that would most likely be considered would be the concept of potential attaching outriggers to the pickup truck if possible. This concept would really give that final touch of stability and surety of the truck being able to remain in place as the trench launcher is being activated. The truck's weight by itself would certainly be able to hold the individual up, but having the outriggers would also solidify that the truck wouldn't move. It hasn't been calculated the amount of force that would be applied to a truck vertically lifting up a human being and his/her equipment, but having that extra step of precautionary action to lock in the truck could make a big difference.

Figure 1 is the first hand-drawn rough sketch of the idea of a diagram including the idea of the vest and where the loops for the hooks will be located.



(*Figure 1*)

Now that the general description of this device has been further explained, the plan for this idea is to use this as a new and exciting alternate form of trench safety to save lives as much as humanly possible.

Background

How This Came About

The idea of this product was primarily thought of through a Cal Poly heavy civil class. One of the classes discussions for the day was regarding along the lines of trench safety, and the collected interpretation from this particular discussion just seemed that there wasn't really a lot of successful alternative solutions to trench safety aside from having to escape up ladders before the trench collapsed and some of the previously mentioned precautionary action. One day, the idea of having someone being vertically launched up in the air seemed like a more attractive idea for means of efficiency and success due to its fascinating features. It creates a new and fresh concept that will hopefully revolutionize trench safety to a new degree. Respectfully, ladders do work, but has grown to be seen passed its time, and having something that can hopefully save more people and not have the people in the trenches rely on their own physical capabilities will surely increase the success rate of saving individuals from cave-ins and shoring failures. The concept of the trench launcher, alongside all of the precautionary action from previous jobsites, will indeed increase more of a stable and solidified structure to protect people from harm. Since safety will always be one of, if not the biggest, aspect in construction, it's important that striving for improvement and finding new ways to further develop the construction industry is beneficial in any way.

Methodology

The methodology provided, will focus on advantages in this product showing where it will be effective and resourceful for the safety of those working in the trenches, the disadvantages with possible answers of where these concerns can be improved or solved, ideas to further develop the device, and finally a topic of interest on whether the safety personnel would use the product on their jobsite once physically developed. The sample of people interviewed were primarily safety managers and other safety personnel from reputable construction companies such as DPR Construction, Pankow, Hensel Phelps, Granite Construction, and PCL Construction. The primary plan of attack is to describe to them the idea of this new product, and then further discuss pros, cons, ideas for improvement, critical changes that may factor the benefit of the product and safety of trench workers, and finally common input that will improve this concept in the best way possible. Having their professional feedback from the interviews will significantly be insightful, and also receiving their input with a third-person perspective truly will be beneficial to this study due to their number of years of experience in the world of construction and particular specialty along the lines of safety. The questions during the interview process for these professionals include the following:

- What advantages do you see in a piece of equipment like this involving trench safety, safety of the individual inside and general input?
- What disadvantages do you see in this piece of equipment in regards to safety of the individual and general input?
- Any suggestions, additions, or ways to improve this device?
- Any questions about the product itself?
- If you had the opportunity to use this product on one of your jobsites, would you consider using it?

The interviewees are well experienced individuals whom all have had numerous years in the construction industry, exceling and specifying their career, or have had previous experience, in safety. Below are each individuals interviewed, their position, and what company they work for:

- Vanessa De La Torre, HSE Supervisor for PCL Construction
- Jon Gregg, Safety Manager for DPR Construction
- Joseph Lake, Safety Manager for Hensel Phelps
- Dana Bednarik, Safety Manager for Granite Construction
- Oscar Jimenez, Safety Manager for Pankow
- Peter Loeb, Project Executive for Pankow

After we complete each interview, discussing mainly the advantages and disadvantages/changes, we will develop a final conceptual idea of this machine that will be our "finalized model". Since this idea is still in the beginning

stages, we're going with strictly conceptual ideas, because we have to ensure that this machine is a more feasible and presentable piece of equipment to commence ideas like calculations, testing, and building of the prototype. It's important that this launcher is perfect, because the safety and life of all of the individuals inside the trench are depending on the success of this product, and it's crucially important to consider their safety as a priority. Having an open-minded conversation with everyone will surely create some interesting ideas, but all for the sake of progress and success.

Below will be the results summed up as a whole from every piece of feedback provided.

Results

After further review and interviews with our professionals, we have collected all of the great feedback from each person listed above and our team. The results begin with the positive aspect of this idea that can benefit the success rate, process of development, and most importantly the increased chances saving lives on the jobsite. Continuing after all of the positive aspects, the next area of focus will be the questionable aspects of design and area for improvement. Obviously, every product that is made isn't going to be perfect from the initial standpoint, so having these questions, hypothetical situations and areas of concern will lead to more productivity and less surprises as we further excel the progress of this machine when necessary. Finally, with the pros and cons of this product established, there will be the final result and design of this particular machine from all of the collected datum from our team and safety personnel.

Positive Aspects of Design

From the collective discussions with the selected personnel of the construction industry, we all agreed upon several factors that can leverage the advancement in trench safety involving the trench safety launcher. From the conducted interviews and coordination, prior and after the interview, these professionals gave their positive insight on this product on how they felt personally about this piece of machinery. The following provided include:

1. The idea of the trench launcher being attached to a pick-up truck, similar to that of a tow truck, is indeed effective for usage, mobility, convenience, and stability.

    a. With the trench launcher attachment being installed onto a pick-up truck, the mobility of getting this piece of equipment around the jobsite, especially if it's a relatively larger jobsite, can make it accessible throughout each trench when needed.

    b. The convenience of having this attachment on the truck, makes it incredibly simple for bringing this gadget around each trench. Since it's installed on the truck, concepts such as freeway accessibility make it even more a benefit for modes of transportation to the jobsite itself.

    c. Having the support of the trucks weight does in fact make it possible for the launcher to lift up the combination weight of the individual and their gear off of the ground at a safe speed due to its counterweight of the vehicle. Also, since the truck would be heavier than the individual by a significant number makes it more reliable to depend on the balance and stability of remaining secure.

2. The idea by itself is considered a better, safer, and more reliable alternative in compared to what the protocol is before and has less pressure on the individuals in the trench. Given that the current OSHA approved protocol for shoring failures and cave-ins is sheerly off of the construction workers to running and climbing up ladders that are 25 feet from each other, their physical capability won't have to be a concern in compared to this launcher.

3. The two-way button system between the competent person and the individual inside of the trench will maximize efficiency and precautionary action. Since there will be a significant amount of background noise, having multiple eyes and ears paying attention to the worker's safety is exceptionally effective for saving the lives of those working in the trenches.

4. One topic that was brought up was the concept of this product being reusable. Having multiple uses surely makes a great point for saving money and keeping the budget for this product.

Questionable Aspects of Design/Room for Improvement

Along with the numerous advantages that this piece of machinery has to offer for the construction industry and trench safety as a whole, there is always room for improvement and general areas of concern about this product that could lead to potential issues in the future. With any new invention for any type of field of subject, there's going to be obstacles to cross, and having constructive criticism from experienced professionals certainly helps to making the best product possible. The following provided include:

1. Making sure that the harness is properly placed so that the individuals' feet, legs, or other body parts don't get caught in the dirt, leading to spinal damage, neck damage, and other serious injuries. With the proper placement of the hooks being attached via two by the shoulders and two by the hips, it'll properly lift the person from the ground in more of a flatter and horizontal position, keeping them from being stuck in the dirt prior to it touching them.

2. Another concern that can lead to complications is having multiple individuals in the trench at a time. This kind of concern can lead to people potentially colliding into each other, miscommunication of whom is being launched, and the capability of whether one or more launchers can lift individuals. The solution considered would be having multiple trucks with attached launchers place in safe distances around the trench.

3. Joseph Lake did mention a pretty reasonable question of concern for a product like this. Since trench safety is such an unpredictable system of events that can lead to a wide variety of potential critical issues, along with this machine will require a great defense system of lawyers to protect a lot of people and companies from being sued in the beginning stages of development of this item. Even with proper training prior to the usage, there's still going to be a lot of grey area on the products success rate.

4. The issue of companies hopping on board with this item with it being so risky with peoples' lives can definitely lead to many complications with people committing to this item via funding and using it on their jobsites.

5. Pricing would be another complicated situation due to the prices of ladders in compare to the installment and usage of the trench launcher. It's understood that indeed that ladders are a cheaper option and still has a relatively decent success rate, but that is strictly relying on the physical shape and condition of the individual in the trench. Having a person with potential health problems could lead to a less success rate of safely getting out of the trench, and with the trench launcher, they would have to rely on that. The quality of life and safety of the jobsites workers is priceless in regards to safety.

6. One of the most concerning and dangerous issues that can lead to furthering the problem would be the situation of if the person actually getting partially caught in the dirt, leading to the question that Peter Loeb brought during discussion, "what would stop the machine from continuing the jerking motion?" The solution of adding of a disengaging calibrated clutch system would be a great addition to solving this particular problem, so that there would be a possible tension limit turning the machine off and not further increasing the injury/injury risk of the person.

7. The issue of stability regarding this product would also be a serious concern, especially with the amount of force it would require for the machine to lift the individual. Similar to cranes, there's weight limits on certain angles of the boom and stick. With that being said, an issue similar to that could be solved with an integrated locking system that would lock the joints between and on the edges of the boom and stick. Having this would prevent the higher parts from swiveling which would also prevent rocking and unnecessary movement with the boom and stick while lifting the individual.

8. An obstacle that Vanessa De La Torre brought up that can lead to complications is the idea of cross-bracing getting in the way. This can lead to confusion before the use of the machine and can also limited the area of freedom to vertically launch the individual up in the air. The potential solution is most likely going to be not using this particular product if there is cross bracing, but maybe in other forms of trenches and excavation

9. The last area of concern, that actually the majority of our interviewees brought up, was the concept of the slack from the cables being on the ground leading to tripping hazards and inconveniences for the workers. The idea of potentially just having the right amount of slack not touching the ground, but also not limiting the movement of the person inside is going to be the best solution for this topic of analyzation.

Final Developed Piece

After all of the interviews, input, and further discussions the safety personnel and team, we have come to a final conclusion and proper layout of this launcher, and we're going to go with the following idea. The basic concept from the introduction above most certainly will have a lot of the same components maintained, but now the ideas of our extended precautionary action will be added and taken into place. The prerequisites of training, testing and new additions for the future are definitely noted. They will become probably the most important aspects to include to ensure that the safety of those attached to the launcher will be indeed the most critical point of interest. Additions from the future research area below, like the calibrated clutch system, a sensor that will track and follow the person within the trench and finally the inclusion of the automated airbag protection kit equipped within the harness surely makes for great attachments to incorporate with the final design.

Conclusion

Now that we have been given the background from our research, received exponential feedback and input from our safety interviewees, it's clear to see that the original idea did have its moments and its potential to be something useful for the construction industry, but the final idea surely added more insight and a more reliable structure in this piece of machinery. After receiving a 100% approval from our interviewees related to the question of, "If you had the opportunity to use this product on one of your jobsites, would you consider using it?", with proper training and testing of course, we have the upmost confidence that this product is feasible and can potentially lead to a new a revolutionary device in the world of construction.

In retrospect, the procedures of interviewing these professionals really came in handy with the process and development leading to the final product. The appreciation is surely noted, and with their countless years of experience in the world of safety, this item couldn't be what it is without their insight and input regarding its headway of the conceptual idea for this trench launcher. Clearly, there's so many "what if" situations in construction due to so many factors that can lead to disaster, but having those types of unfortunate events occur will lead to less mistakes, increased progression, and a more well-rounded product in the making. The assumptions of having more of these questionable aspects compared to positive aspects were surely expected, and honestly more necessary, but it seems like these topics are more appropriate for this topic of interest since its design is still so new.

The future is bright for this product, but there's still a long road ahead of work, calculations, funding, and many other bridges to cross. The determination and upmost confidence in this piece of machinery could lead to many new segues to new development, opportunities, and future research to strive for constant improvement not only for this particular item of interest, but for construction as a whole.

Future Research

Now that we have a completed and more elaborated concept of this launcher, we can now commit to developing further research ideas, concepts, and testing to further stretch our goal of creating a life saving device in the construction industry. It's important that the numerous steps below are noted and well concentrated, because this device will indeed still have a lot more work and calculations to make it an actual functioning device. Clearly this

idea is well in the early stages of development, and having these concepts noted and thought out will ensure that this device is actually ready for the field when the time has come.

With this piece of equipment still being so new, there's obviously a wide variety of items to consider for future research for this product. Below are some ideas and explanation of how it can be relevant to this product.

- Prototype
    - Since the conceptual idea is now developed, the artistic approach of creating finalized and professional drawings, and a prototype model of this to demonstrate to our users will most certainly be processed for further development and progress of this model.
- Certain equipment and models that would satisfy the process
    - We can further our research and find certain models of equipment to attach to this launcher to make it more of a realistic and tactile piece of machinery. Once we have all of the pieces of the puzzle put together, we can further develop things like the budget/price of how much it'll be to build, develop, and sell the final model.
- Tests of successful launches
    - After the team has commenced a prototype and attached all of the equipment, it's time to ensure that this concept is indeed applicable in the construction field. It's important that this idea gets tested to guarantee that this product is one, usable, and two able to safely get people out of the trench with no harm to the machine and most importantly them.
    - Once enough successful testing has been commenced, the next goal would get it OSHA or ANCI certified.
- Training once ready
    - Once this item receives testing and a high success rate, the next steps would be to provide training for this object. Obviously, people would need to know how to use this machine safely, and having proper training would most certainly be crucial for the success of this product.
- Future equipment after the base model
    - With the necessary pieces of the product already established, there can always be room for additions and complimentary attachments can be assigned to the launcher. Additions include:
        - Sensors on the tip of the stick and part of the vest to hover over the individual in the trench so that the tip remains vertically above the person as they move around doing their work.
        - A really interesting future attachment for this product, brought up by both Oscar Jimenez and Jon Gregg, was the idea of using a cushioning airbag system to equip into the harness in a sort of precautionary action. The idea similar to that of the life preserves on aircrafts that have an almost instantaneous deployment would surely give the person more cushion protecting their vital organs from the pressure of the dirt.
        - Another great attachment idea that was brought up by Dana Bednarik, was the idea of making an attachment onto a backhoe/excavator substituting the idea of it being in the back of a pick-up truck. It certainly has the reach and supported weight to lift an individual off of the ground safely, and having that might actually be a cheaper option than the original idea as a whole.

References:

Hinze, J. (2005). The nature of struck-by accidents. *Journal of Construction Engineering and Management*, *131*(2), 262–268. https://doi.org/10.1061/(ASCE)0733-9364(2005)131:2(262)

Teizer, J. (2017). Mobile point cloud assessment for trench Safety audits. 157–164. https://doi.org/10.22260/isarc2017/0021