Pathiraja, G.A.P.C.S.M., Piyumra, R.A.D. and Disaratna, P.A.P.V.D.S., 2024. Challenges in chemical anchoring carried out in the Sri Lankan context. In: Sandanayake, Y.G., Waidyasekara, K.G.A.S., Ranadewa, K.A.T.O. and Chandanie, H. (eds). *Proceedings of the 12th World Construction Symposium*, 9-10 August 2024, Sri Lanka. pp. 365-378. DOI: https://doi.org/10.31705/WCS.2024.29. Available from: https://ciobwcs.com/papers/

CHALLENGES IN CHEMICAL ANCHORING CARRIED OUT IN THE SRI LANKAN CONTEXT

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ABSTRACT

Adhesive anchoring has achieved rapid growth in the construction industry, due to the numerous advantages that it offers over conventional joining methods. Particularly, in Sri Lanka, the adhesive or Chemical Anchoring technique is widely used in the field of construction. This research investigated potential challenges that can be faced in Chemical Anchoring and carrying out strength tests in the Sri Lankan context to overcome those challenges while getting maximum output to the construction. Following the qualitative approach, eleven semi-structured expert interviews were carried out to collect the data while adopting manual content analysis as the analytical tool. According to the findings of expert interviews, poor workmanship is the basic challenge identified in Chemical Anchoring in the Sri Lankan context. It is the ground for most of the other challenges. Hence, proper supervision, adherence to manufacturers' recommendations, and the product manual designed for the Sri Lankan context will be the best approach to overcome them. With the use of designing software for Chemical Anchoring, under-design, and over-design which are the common errors in industry, that can be mitigated. The research study proposed solutions to issues in Chemical Anchoring process to enhance the performance in the construction sector.

Keywords: *Anchor Application; Challenges; Chemical Anchoring; Construction; Sri Lanka.*

1. INTRODUCTION

Cast-in-place anchors and post-installed anchors are the two main types of anchors used to provide connections between concrete and structural parts (Mazumder et al., 2020). According to the same source, chemically bonded anchors have become increasingly popular in Turkey for retrofit applications since the 1999 Kocaeli Earthquake. Chemical anchoring refers to the process of installing a new element, such as brick or concrete, to an existing structural element using a chemical mixture or highly reactive resins (Çalışkan et al., 2022). When strengthening and repairing older structures with inadequate seismic performance, chemical anchors are commonly used (Mazumder et al., 2020). The adaptability of the new structure depends on the bonding between the reinforcement of

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the structure and the reactive resins and the base material (Cook, 1993). Hence, choosing the proper materials helps to ensure the full bonding of the chemical anchor (Çalışkan et al., 2022). According to Mazumder et al. (2020), Chemical Anchoring is widely used for post-installed reinforcement because of its cost-effectiveness and efficiency in application. Moreover, Müsevitoğlu et al. (2020) revealed that the primary reason of why chemical anchors is preferred is that they are greatly convenient to the user in the design, application and planning process. In addition to that, Chemical Anchoring has the potential to deal with most of the issues that occur in mechanical anchors and reacting mixture or reactive resins used in boreholes while having the opportunity to make slight adjustments to the stud's alignment (Çalışkan et al., 2022). The durability and strength of chemical anchors can be influenced by several factors, including curing, the chemical composition of the reactive resins, drilling depth, cleanliness of the borehole, the method of injecting chemicals into the hole, and the technique for inserting the steel rod into the drilled hole (Mazumder et al., 2020). To ensure the strength of the chemical anchors, various strength tests such as bench impact tests and pull-out tests are employed in the industry to measure the strength of these chemical anchors (Titov et al., 2022).

In the Sri Lankan context, Chemical Anchoring is widely used in road construction building construction and dam construction (Thienoosan et al., 2023). Nevertheless, practical anchoring applications encounter various issues. As to Bayraktar et al. (2016) and Karakotas et al. (2005), the primary issue is the poor quality of the concrete in the current construction that is intended to be reinforced (Müsevitoğlu et al., 2020). Therefore, it is imperative to conduct an in-depth study to identify the potential challenges associated with the Chemical Anchoring process in the Sri Lankan construction sector to ameliorate the efficacy and quality of the Chemical Anchoring process. Apart from that, previous research studies primarily focused on the tensile behaviour of Chemical Anchors (Kim et al., 2013; Müsevitoğlu et al., 2020), developing codes for Chemical Anchoring (Stierschneider et al., 2022), shear capacities (Yilmaz et al., 2013). On the other hand, numerous studies have been carried out on current chemical anchor systems in construction elaborating on the basic concept of bonded anchor systems (Kim et al., 2013; Yılmaz et al., 2013). Their design, load-bearing capacities, load-bearing behaviour and chemical compositions of highly reactive resins that are used to bond the anchor and base materials have been intensively studied over the past years (Eligehausen et al., 2006). Nevertheless, neither research study has deeply investigated the challenges associated with the Chemical Anchoring process, which is evident that there is a prevailing research gap regarding this matter. Therefore, to fulfil both the industrial need and perceived research gap this study aims to investigate the challenges that can be encountered in Chemical Anchoring. The following objectives were achieved; to study the concept of Chemical Anchoring, to identify the application of Chemical Anchoring, to investigate the challenges encountered during Chemical Anchoring and to propose possible solutions to overcome them.

2. LITERATURE REVIEW

2.1 CHEMICAL ANCHORING

Sabatini et al. (1999) have identified anchors as structural elements installed in soil or rock, or other base material that is used to transmit an applied tensile load into the ground or other structures. Xanthakos (1991) states that the purpose of anchors is to act as load-carrying elements, consisting essentially of a steel tendon inserted into a suitable formation or structure in almost any direction.

2.1.1 Bonded Anchors

Connections to concrete include both cast-in-place and post-installed anchors. Post-installed anchors are either mechanical or bonded anchors (Cook et al. 2007). According to Eligehausen et al. (2006), bonded anchor systems can be identified as anchors bonded into concrete with the aid of chemical and non-chemical components. A bonded anchor comprises a threaded rod, a washer and hexagon nut, and a resin motor. Cattaneo and Muciaccia (2015) stated that bonded anchors are even very popular because of their flexibility. Moreover, as Sakla (2005) declared bonded anchors are increasingly employed as structural fastenings to hardened concrete. Types of the bonded anchor systems are identified in Figure 1.

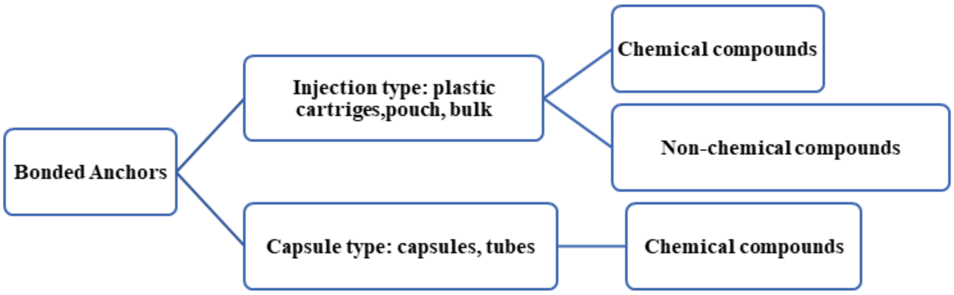

Figure 1: Types of bonded anchor systems in concrete

Sakla (2005) has stated that an adhesive anchor is installed using a reinforcing bar or threaded rod inserted in a drilled hole in hardened concrete using a polymer-based bonding agent including epoxies, vinyl esters, and polyesters. Collins et al. (1989). AI-Mansouri et al. (2019) have investigated two advantages of these adhesive anchors i.e. (i) ease of implantation, and (ii) their high load-bearing capacity at ambient temperature for deep embedment depths.

2.1.2 Application of Chemical Anchoring

According to the Ramset anchoring resource book (2009), the principal applications of chemical anchors in construction have been identified as structural beams and columns, batten fixing, installing signs, handrails, balustrades, and gates, racking, safety barriers, stadium seating and machinery holds down. In addition, chemical anchors are ideal for high-stress applications, such as seismic zones or high-wind locations, and for safety-critical situations where exceptionally high loads must be supported. This is because they form an excellent bond between the anchor and the substrate (Budhai, n.d.). Cook et al. (2007) have revealed that the nature of the drilled hole, concrete compressive strength, type of aggregate, curing period of adhesive, method of hole drilling, and temperature effects are the governing factors of bond strength of chemical anchors.

2.1.3 Process of Chemical Anchoring

The correct installation technique must be employed to ensure a stable anchor that meets load-bearing requirements and withstands the test of time (Budhai, n.d.). According to the Ramset anchoring resource book (2009), the installation of a chemical anchor has been described step by step as shown in Figure 2.

Capsule Method

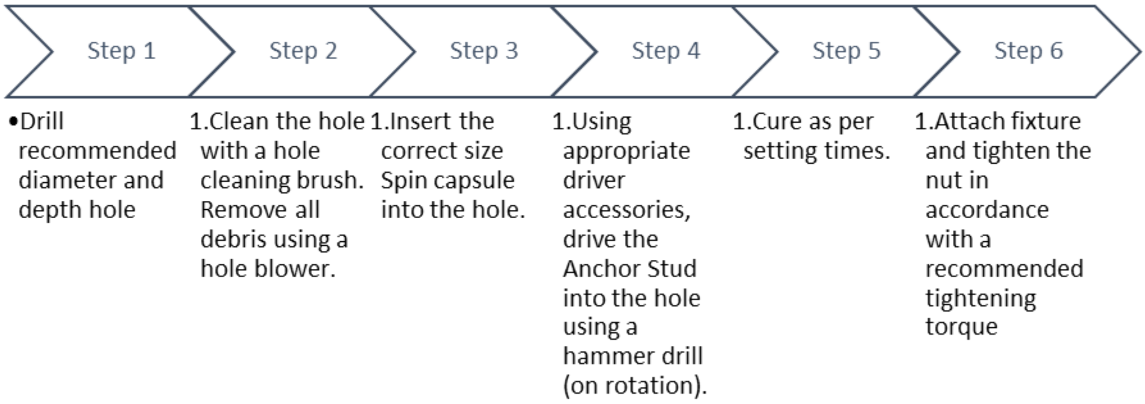

Figure 2: Capsule method

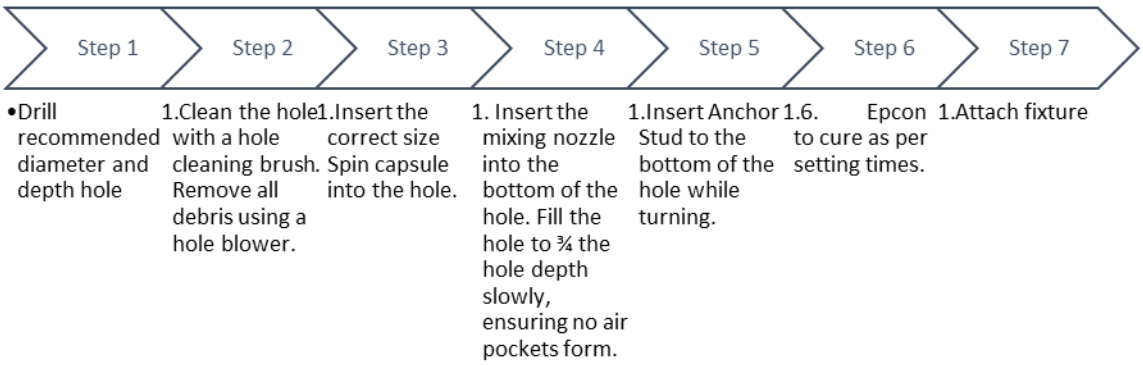

Figure 3: Inserting method with gun

3. RESEARCH METHODOLOGY

To study the challenges associated with chemical anchoring applications, a qualitative research approach was adopted, as it allows for a deeper understanding of the issues from the experts' perspectives (Ospina, 2004). Moreover, due to its exploratory nature, the qualitative research approach is a beneficial strategy when researching a phenomenon for which there is limited accessible information (Taherdoost, 2022). Expert interviews provide rich and detailed information on the research topic from the perspectives of individuals with specialised knowledge or experience (MacDonald & Headlam, 2011). Because it enables researchers to obtain comprehensive data and supporting documentation from respondents while taking the study's topic into account, the semi-structured interview holds greater significance in qualitative research than another interview format (Belina, 2023). Moreover, as this approach offers greater flexibility with appropriate guidance for the researcher (Munianday et al., 2022), eleven semi-structured interviews were conducted to collect the data. Each interview was conducted either face-to-face or online and lasted approximately 30 to 40 minutes. The experts were selected using a purposive sampling technique, which allows for gathering information to ensure maximum diversity within the sample (Weerasooriya et al., 2024). The experts were selected based on the pre-determined criteria as delineated in Table 01.

Table 1: Profile details of the interviewees

Code	Compulsory Requirement (Satisfy all)		Additional Qualification (satisfy at least two)		
	10+ years' experience in the Construction Industry	5+ years' experience in Chemical Anchoring	Having bachelor's degree related to the built environment	Having post-graduate degree related to the built environment	Interest in sustainability practices
E1	✓	✓	✓	✓	✓
E2	✓	✓	✓	x	✓
E3	✓	✓	✓	✓	✓
E4	✓	✓	✓	✓	x
E5	✓	✓	✓	x	✓
E6	✓	✓	✓	✓	✓
E7	✓	✓	✓	✓	✓
E8	✓	✓	✓	x	✓
E9	✓	✓	✓	✓	✓
E10	✓	✓	✓	✓	x
E11	✓	✓	✓	✓	x

Under compulsory requirements, all the interviewees must have more than ten years of experience in the construction sector and more than five years of experience in Chemical Anchoring. The primary purpose of “compulsory criteria” is to ensure that, the selected experts have the specific industrial knowledge of the Chemical Anchoring process to give more accurate and practical answers to the interview questions. Under, additional qualifications, each interviewee shall fulfil at least two conditions, having a bachelor’s degree related to the built environment, having post-graduate degree related to the built environment and interest in sustainability practices. The purpose of additional qualification criteria is to ensure that interviewed experts have sound academic backgrounds in built environment practices.

According to Hsieh and Shanon (2005), content analysis is the main data analysis technique used for qualitative research. It involves systematically categorising and interpreting the content of a set of data, such as interview transcripts, documents, or images, to identify patterns, themes, or meanings (Leedy & Ormrod, 2015). Therefore, adopting manual content analysis the collected data were analysed accordingly to meet the defined objectives of the study.

4. RESEARCH FINDINGS

4.1 CHEMICAL ANCHORING APPLICATIONS USED IN THE SRI LANKAN CONTEXT

According to the literature findings, post-installed chemical anchors are easy to install and cost-effective. As a result, their applications are increasingly gaining popularity in practice. Many applications can be found internationally; however, in the Sri Lankan context, they are not very popular. Table 2 summarises the chemical anchor applications in the Sri Lankan context.

Table 2: Chemical anchoring applications

Applications	Literature	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11
Structural beams and columns	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Installing signs, handrails, balustrades, and gates	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
To maintain column position		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Base plate application		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Joints between precast concrete units	✓	✓		✓		✓	✓		✓			✓
Fixing in stone							✓	✓	✓		✓	
Safety barriers	✓	✓					✓					
Batten fixing	✓						✓					
Racking	✓						✓					
Starter rebars for staircase							✓		✓			
Missed rebar in pile caps							✓		✓			
To extend existing slab part									✓		✓	

All the interviewees have experienced Chemical Anchoring in structural beams and columns and in installing signs, handrails, balustrades, and gates. E1 stated that "*most of the time for structural beams and columns, Chemical Anchoring is done to install missed rebars*". Further, E3 mentioned that "*keeping start-up for handrails and balustrades when concreting is sometimes difficult because they are not usually aligned, So, contractors prefer to go with Chemical Anchoring to install them*". E1 added another application which is maintaining column position as a common application in the Sri Lankan context. E8 introduced Chemical Anchoring as the best method to extend the existing slab part. Further, he said "*But it is not in use most of the time. People always try to go with a conventional method like chipping or breaking concrete until reinforcement appears and then bind them with new steel bars and concrete again*". Those are the applications of Chemical Anchoring that can be found in Sri Lankan practice.

4.2 CHALLENGES ENCOUNTERED IN CHEMICAL ANCHORING AND POSSIBLE SOLUTIONS TO OVERCOME THEM

4.2.1 Challenges Faced During Selecting a Chemical Anchoring Method and Proposed Solutions

The expert interview guidelines focused on studying potential challenges that might be encountered at the stage of selecting the Chemical Anchoring method. Accordingly, it was revealed that eight obstacles and proposed possible solutions to overcome the identified barriers. Table 3 delineates the findings.

Apart from the challenges, the study focused on proposing potential solutions to overcome the identified obstacle. However, the interviewees failed to suggest solutions for all the challenges. Accordingly, Table 3 showcases both challenges and proposed solutions.

Table 3: Challenges faced during selecting a chemical anchoring method and proposed solutions

Challenge											**Solution**										
Monopoly for one company											Give opportunities for new service providers										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✔		✔			✔	✔	✔	✔	✔	✔				✔						✔	
Not having proper knowledge of chemical types and their characteristics											Workshop for engineers and professionals who are engaged in the design process. Training programs for labourers										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
	✔		✔		✔	✔	✔			✔		✔	✔			✔	✔	✔	✔	✔	✔
Overdesign											Use software when designing. Get designs from industry experts										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
		✔		✔	✔			✔	✔						✔						
Having only one method to do Chemical Anchoring																					
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
	✔	✔	✔		✔				✔												
Under design											Get designs from industry experts. Use software when designing										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
		✔			✔			✔							✔	✔					
The high price of some specific chemical types											Minimize chemical wastage when applying										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✔				✔	✔										✔				✔		
Poor adoption of new technologies											Workshop for engineers and professionals who engage in the design process										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
				✔				✔							✔				✔		
Not having service providers in the rural area																					
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
		✔																			

According to E2, E3, and E6, not having proper knowledge of chemical types and their characteristics is another challenge that can be faced in Sri Lanka. Engineers tend to use the same chemical products for all applications. Further E2 mentioned that:

"*Usually, to cure the chemical it takes five or seven hours under normal conditions and until that time passed, the load should not be applied on rebar. if the contractor wants to cure the chemical and load it within a few hours under any condition, some chemicals have their own characteristics. But both contractors and engineers are not aware of them".*

According to E3, they advise the contractor to cure chemical anchors for 24 hrs because climatic conditions and other site conditions can be changed. E8 mentioned that "because of wet surfaces and water, it takes more time to cure for normal chemicals but there are some chemicals, those conditions do not affect. But they are not in use because engineers don't know about them*".* Further E2 mentioned that *"*when selecting chemicals for anchoring for green concept projects, engineers should be aware of VOC (Volatile Organic Compounds) level of the chemical. Otherwise, the green certificate cannot be gained for the project*".* As stated by E5, E6, E9, and E10, usually, chemical anchors are overdesigned in Sri Lanka, resulting in additional cost and time.

Moving onto solutions, most of the interviewees suggested workshops to educate industry professionals who are engaged in the design process of the chemical anchors about the chemical types, their characteristics, and new technologies used. According to E2, training sessions for labourers are most important, to educate them on standard operating steps and maintain that equipment. It helps to minimise chemical wastage.

E5 mentioned that "s*oftware can be used to design chemical anchors now. It avoids over design and under designs*". Getting designs from industry professionals and having contact and checking the design with the support of the technical team of the service providers also helps to overcome this challenge. Those are solutions interviewees suggested for the challenges identified.

4.2.2 Challenges During Installation of Chemical Anchors and Potential Solutions Against the Challenges

The interviewees were asked to give their opinions on what type of challenges would be faced by the professionals during the phase of installation of chemical anchors following the above, possible solutions were suggested by the experts as outlined in Table 4.

Table 4: Challenges during installation of chemical anchors and potential solutions against the challenges

Challenge											Solution										
Poor Workmanship											Proper supervision Use new technologies										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔
Drilling reinforced concrete											Break or chip the clear cover Scan the element to identify the formation of reinforcement										

Challenge											**Solution**										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✓	✓		✓		✓	✓	✓	✓	✓	✓					✓						
Have to minimize the chemical wastage											Proper supervision Follow standards and use the correct consumption chart for chemicals.										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✓				✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓			
Not having proper knowledge and experience											Workshops or training sessions										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✓	✓			✓		✓	✓	✓		✓	✓	✓			✓		✓	✓	✓		✓
Not having the required instrument											Getting service done by a reputed company										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✓	✓			✓		✓	✓	✓		✓					✓		✓	✓	✓	✓	✓
Having difficulties reaching the exact location											Identify client requirements properly at the design stage Avoid design and construction errors or mistakes										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
	✓		✓			✓		✓		✓				✓			✓		✓		
No proper storage facilities for chemicals											A separate place to store chemicals under required conditions										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	E11
				✓	✓			✓	✓	✓					✓	✓			✓	✓	✓
Pure epoxy getting cured in the nozzle											Proper cleaning before use										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
					✓	✓		✓	✓	✓						✓	✓		✓	✓	✓
Hazardous chemicals											Wear gloves and eye protectors										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
	✓			✓	✓	✓				✓		✓			✓	✓	✓				✓

Accordingly, nine challenges were identified and propose one or two solutions for each identified barrier.

Poor workmanship is the main challenge in the Sri Lankan context. Labourers do not follow the standard process when installing chemical anchors. E2 mentioned, "n*o proper cleaning is the main challenge we face in Chemical Anchoring. Bond strength is reduced because of the dust in the holes*". The reason for this is chemicals tend to bond with the dust but not with the concrete. Further E2 described "n*ot setting required parameters like depth, holes diameter, drill cut size according to bar size is another challenge*". According to E6 and E8, drilling the hole perpendicularly is important to get the required load strength to the anchors. When reinforcement appears during drilling, labourers tend to stop the drilling or try to deflect the hole. Further E7 mentioned that "*when applying chemicals to the hole, if air bubbles remain inside the holes, required bond strength can't be gained. Also, those air bubbles can be exposed making injuries to the workers*".

For most of the challenges identified in this stage, proper supervision is the possible solution that can be taken. Apart from that, awareness programs and workshops are another possible solution for some challenges. According to E5, using new technologies avoids poor workmanship. Further for cleaning instead of a brush, using water is more effective to remove dust, and E6 mentioned that "*we must educate the respective persons in the supply chain to store the goods properly*". Following standard safety procedures is more effective than doing treatment for the injuries. E2 mentioned that *"wearing eye protectors, gloves and safety belt is more important to avoid accidents in site"*. Those are the possible solutions identified in the installation stage.

4.2.3 Challenges Faced after Installing Chemical Anchors and Proposed Solutions

According to literature findings, rebar should be inserted into chemicals while turning. During the gelling period, rebar can be adjusted. This is the main advantage of Chemical Anchoring when compared with mechanical anchoring. But after gelling time, rebar should not be disturbed. Otherwise, bond quality will be reduced. Table 5 summarises all challenges respondents identified after installing Chemical Anchoring.

Table 5: Challenges that can be faced after installing chemical anchors and proposed solutions

Challenge											**Solution**										
Tackle the construction program											Identify critical paths and work that can be done simultaneously and redevelop the construction program										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✔		✔		✔		✔	✔	✔	✔				✔		✔	✔		✔	✔	✔	✔
Pure epoxy resins have a high curing time											Use hybrid resins which have relatively less curing time										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✔					✔	✔	✔	✔	✔	✔	✔		✔		✔			✔	✔	✔	
Corrosion of rebar											Use Certified adhesives which resist corrosion										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
				✔			✔	✔	✔			✔	✔		✔	✔		✔			✔
Shear failures											Design chemical anchors where shear is not critical Carry out the shear test before attaching the fixture to the anchor										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✔		✔					✔			✔	✔			✔			✔		✔	✔	
Reduce structural integrity											Minimize chemical anchor applications for structural parts										

Challenge											Solution										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
✓		✓		✓			✓			✓	✓	✓		✓					✓		✓
Change curing period due to temperature and site condition											Utilize a product manual designed for the Sri Lankan context Use resins that have relatively less curing time and less sensitivity to the temperature										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
	✓					✓			✓				✓			✓	✓				
The actual applied load is not provided which results in using larger diameter rebars or high embedment depths											The structural design team should involve the manufacturer from the beginning to have the optimal design										
E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*
					✓		✓					✓			✓			✓			

Most of the interviewees identified that pure epoxy resins have high curing time as a challenge, though the product manual mentions curing time as five or six hours, which changes according to the climate and site condition. E2 mentioned that “if the surface is not dry or wet, it takes much time to harden”. According to E7, when temperature drops, curing time is high. Further E7 mentioned that “in Nuwaraeliya, chemicals have higher cure time than other districts”. According to E1 and E7, most of the time engineers recommend curing the chemical anchor around 24 hours or day. This is the challenge faced by the contractors. If Chemical Anchoring was included during the design stage, it is not a problem because the construction program is developed considering those facts. But most of the time chemical anchors are done for sudden design changes or to install missed rebars. In such a situation curing for a day is a huge time waste and difficult to tackle the construction program.

Further E5 described that “c*hemicals not up to the standard level let the rebar corrode inside the chemical*”, which leads to happen failure in the structure. According to E1, shear failure can happen because usually chemical anchors are not designed for shear, and they are designed where shear is not critical. Yet sometimes after the actual load is applied, shear will be critical for some areas. Those are the challenges identified after installing chemical anchors by interviewees.

5. DISCUSSION

Chemical anchors are perfect for applications requiring high loads since the load they support is nearly always greater than the initial substrate material. There is no pre-loading tension applied to the substrate, unlike with expansive mechanical anchors, because the system is based on chemical and mechanical compounds (Sika Group, n.d.). Chemical anchors are, therefore, perfect for group anchoring and fixing near edges. Nevertheless, the research study revealed a set of challenges faced by Sri Lankan professionals throughout the application of Chemical Anchoring. Eight challenges were identified in the design phase of chemical anchors, with experts proposing solutions for each challenge.

One significant challenge is purchasing materials, as the monopoly market in Sri Lanka limits the availability of Chemical Anchoring materials to just one firm. As a result of the monopoly market, it has been difficult to manage the price of materials (Dai & Guo, 2020). In addition to that, Sri Lanka lags in the application of novel technologies, and the lack of knowledge among professionals has led to both under-design and over-design of chemical anchors. To address these issues, it is crucial to conduct training and workshops and to involve experts in the field of anchoring during the design phase. Experienced workmanship is critical during the installation of chemical anchors. Many anchors fail due to poor workmanship, failure to find the correct depth, limited chemical availability, and a lack of advanced tools and materials. Proper supervision, adopting new technologies, and implementing proper designs are the primary solutions suggested by the interviewees. In Chemical Anchoring, the anchor hole must be cleaned well, as chemicals can be damaged when mixed with debris in the holes. After the installation process, to address the challenge of maintaining the construction schedule, most interviewees recommended identifying critical paths. Corrosion is another issue practitioners face after Chemical Anchoring, and it was recommended to use adhesives to resist corrosion. Taking longer curing times can be managed by replacing pure epoxy resins with hybrid resins. Moreover, utilising product manuals designed for the site conditions can manage the changing curing times resulting from temperature differences and site conditions.

6. CONCLUSIONS AND RECOMMENDATIONS

According to the study, adhesive anchors mainly find their use for repairing, strengthening, and reinforcing existing structures, connecting two similar or dissimilar materials, and resisting mechanical and environmental loads. The applications of Chemical Anchoring are discussed in the literature review. Expert interviews revealed the potential challenges that could be encountered during the design stage, installation and after installation of chemical anchors and proposed solutions. Newly added challenges which arise due to the pandemic situation and economic crisis can be identified as significant increases in chemical prices, lack of chemicals in the stores and supervision. As solutions, designing software can be introduced to overcome under-design, cover design and other mistakes in designing. Moreover, proposer supervision, adopting new technologies, and following proper standards are solutions for the identified challenges.

This research contributes to the industry by identifying potential challenges in Chemical Anchoring and proposing solutions. Further, the study contributes to the theory by addressing the prevailing research gap of none of the studies carried out focusing on Chemical Anchoring within the Sri Lankan context. The research study is limited to the post-installed chemical anchors where the base material is concrete and bricks. Rock anchoring, mechanical anchoring, and grouted anchoring are not considered when carrying out this research.

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