

The practice of bond breaker application in concrete tilt-up construction

by

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Abstract

As concrete tilt-up construction continues to grow both nationally and internationally, accompanying this growth is the use and application of bond breakers. A bond breaker is a material that is used to prevent adhesion of newly placed concrete to the substrate, it is available in several forms including liquid, tape, and spray. Perhaps no other chemically manufactured product is more poorly understood or misused as bond breakers. The following report examines the current practice of bond breaker application in concrete tilt-up construction in the United States through an anonymous electronic questionnaire survey. The survey sought to evaluate the level of communication and knowledge for proper application of bond breakers between industry professionals across this sector of the concrete industry. The survey sought to identify potential barriers and miscommunications in their procedures of bond breaker application. Comparing the survey's results to the manufacturers application recommendations revealed an industry wide inconsistency of bond breaker application and weather considerations affecting the application procedure. This study aims to bring awareness and to bridge the gap of inconsistent practices involving bond breaker application by determining the sources of miscommunication that could cause the misuse of these products.

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Chapter 1 - Introduction

Tilt-up construction is one of the fastest growing industries in the United States which combines the advantages of low maintenance, durability, and speed of construction to provide a reasonable cost (TCA, 2018). The American Concrete Institute (ACI) documents, *ACI 318 Building Code Requirements for Structural Concrete* and *ACI 551.1R Guide to Tilt-up Construction*, defines tilt-up as a “construction technique for casting concrete elements in a horizontal position at the job site and then tilting them to their final position in a structure.” Over 10,000 buildings, enclosing more than 650 million square feet are estimated to be constructed each year using this method of construction (TCA, 2018). In order to successfully and efficiently build a tilt-up project, extensive coordination between the contractors is required throughout the construction process. Many factors must be considered when placing and finishing site-cast tilt-up panels. One of the most vital factors is the proper selection and application of the bond breaker to the casting surface. *ACI Cement and Concrete Terminology* defines a bond breaker as a substance used to prevent adhesion of the newly placed concrete to the substrate. A thorough understanding of the role and application of bond breaker is critically important to achieving a successful tilt-up project, and thoroughly understanding its role and the application method can produce positive results such as successful lifting of the panel (Al Engelman, 2005). This may not be occurring in practice due to miscommunication or lack of knowledge about the products by the worker applying the bond breaker.

This report aims to identify the inconsistencies of bond breaker application by analyzing response data from an anonymous questionnaire administered to industry professionals such as suppliers, subcontractors, general contractors and design professionals. The purpose of the survey was to identify the tilt-up construction industry’s most commonly used types of bond

breakers, typical bond breaker application practices, discrepancies between the manufacturers' guidelines and actual application practices, and varying opinions between the construction/design professionals. Once the discrepancies were identified, correlation of these inconsistencies with the manufactures' provided guidelines was performed to develop improved bond breaker application procedures. The survey consisted of 38 questions that covered multiple aspects of the respondents' experience with bond breakers and their application process. These questions addressed subjects such as weather considerations, type of bond breakers commonly used, slab finishing/curing processes, and the respondent's general knowledge of the tilt-up process. Although the survey as a whole could provide potential insight into other concerns and issues involved with release agents, this report specifically focuses on five of the survey's questions and their responses. These specific questions and results will be highlighted further in Chapter 5 – Data Analysis of this report.

Chapter 2 - Literature Review

Limited literature has been published on studies focusing on the performance and use of bond breakers for tilt-up concrete panels.

Engelman 2005 *Tilt-up Construction Basics to Concrete Construction* article indicates that during the construction process of a tilt-up project many questions may develop, but the fundamentals of a typical tilt-up project are constant. Describing the basics of tilt-up construction, Engelman provides construction process specifics for forming, placing, and finishing of the concrete tilt-up panels while discussing the importance and misconceptions of these construction basics. The majority of the article focuses on the importance of the bond breaker application, stating that a “bond breaker can make or break a tilt-up project, and thoroughly understanding its role and the application process can produce successful project results” (2005). Engelman introduces some key aspects of a bond breaker and its application procedure including chemical compatibility, the rate and methodology of application, weather considerations, and potential consequences when the bond breaker is incorrectly applied.

Chemical compatibility between the curing compound and the bond breaker is essential to any tilt-up project. Engelman recommends, if any uncertainty of compatibility exists, one should verify their chemical compatibility by applying the curing compound and the bond breaker to a test panel in a similar sequence as construction before proceeding with construction of the actual panels or simply request the manufactures to verify the compatibility (2005). If not properly reviewed, some instances of incompatible chemicals have created an adhesive reaction which is detrimental to the lifting procedure of the panels. Other potential problems are compatibility with future surface treatment, such as, the interaction with adhesives for carpet and tile, or affect the time required to finish the exterior (2005).

When verifying and reviewing the chemical compatibilities of curing compounds and or bond breakers there is typically a definitive answer that can be reached through proper research. Unfortunately, when the discussion and questions regarding the application process of bond breaker come about it is difficult to effectively reach a definitive answer due to differing personal opinions and established practices. Engelman states, “that for every project the manufacture should always be consulted for the best product” (2005). Engelman goes on to explain that due to numerous factors that must be considered, the typical practice of bond breaker application varies widely across the industry. He concluded his discussion of this part of the construction process by providing a guideline for applying bond breaker. Table 1 provides a summary of Engelman’s guidelines. His guideline can be viewed as providing the basics of bond breaker application and act as a comparison to the responses from the questionnaire that are addressed in this report. In conclusion, Engelman states “that the bond breaker should be chosen carefully, and the manufacture’s guidelines should be strictly followed” (2005). In industry, it is not clear if this practice is not being strictly followed, which may be leading to detrimental effects on the project’s tilt-up results and construction schedule.

Table 1 - Engelman's Guideline for Applying Bond Breaker

Engelman's Guideline for Applying Bond Breaker
Before spraying, clean the surface of any substance that would impede the bond breaker or stain the panel.
During a hot or excessively dry conditions, it is recommended to fog spray before applying bond breaker.
Two or more coats of bond breaker are generally applied, each successive layer at a right angle to the prior coat.
The bond breaker should be applied a few days before pouring the panel.
To check the effectiveness just before pouring, sprinkle a few drops of water on to the slab, if the water beads up the bond breaker is adequate, if the water soaks into the slab the bond breaker should be reapplied.
During concrete pouring, vibration is recommended but must be carefully done to ensure that the vibrator does not touch the slab because this can cause separation of the bond breaker to the floor slab.

An anonymous case involving tilt-up construction was posted on Concrete Construction (1990) where it was reviewed and responded to by the Concrete Construction staff. The dilemma involved several 8-inch tilt-up panels, cast on a 6-inch casting slab, in which the construction crew was having difficulties lifting the panels off the floor slab. The post states that “the lifting process was unsuccessful even after attempting to wedge the panel free.” The post also indicates that the construction crew either inadequately or completely forgot to apply the bond breaker to the casting slab prior to placing the concrete for the panels. This post was requesting assistance and recommendations to resolve their problem. The staff at Concrete Construction replied to this anonymous case with a few potential solutions after they consulted

with Peter Courtois from Dayton Superior Corporation and a past president of the Tilt-Up Concrete Association. Courtois confirmed that the available alternatives for panel releasing problems are wedging, jacking, and freezing. He also expressed that an economical alternative that had been used for some large jobs is to fill any openings in the panel and raise the elevation of the floor slab which also acts as the casting slab. The Concrete Construction Staff concluded their response with an outline of a procedure for applying bond breaker similar to Engelman's. Both these guidelines offer a simple procedure to ensure the proper application of bond breaker but neither of them assures how this information will reach those who need it most, the field crews applying the bond breaker. The industry as a whole recognizes the importance and value of bond breakers, but it does not emphasize the necessity of proper communication between contractors especially during the application process. The industry needs to create a "Best Practice" guide on how best to communicate the necessary bond breaker application techniques, similar to how Tilt-Up Concrete Association produced its "Best Practice" guideline for adhesive application for architectural reveals after the OSHA 1926.1153 Respirable Crystalline Silica Standard for Construction ruling in September of 2017 took effect.

During the 2018 annual Tilt-Up Concrete Association (TCA) Convention in Miami, the organization members spoke with several contractors who were impacted by the new OSHA 1926.1153 regulation. As part of these conversations, the organization recognized a need for development of a best practice guide related to how the adhesives are to be used in the construction of tilt-up panels that feature reveal strips. Mark Lentzkow states that "it is because most people have never been taught how to properly use adhesives, and, in some cases, they have developed some bad habits" (2018). In his article to TCA, Lentzkow breaks down some of the key points for glue application including materials, temperature, water, and clean up. Each

section goes into detail describing best practices, tips, and tricks to help achieve a successful glue-down job. Lentzkow concludes his piece by stating “Tilt-up is an incredibly complex industry, and very rarely does one size fit all. These best practices are designed to act as a guide and to create a framework for success. This is by no means an exhaustive list.” (Lentzkow, 2018). A similar approach should be taken in the application process of bond breaker. TCA needs to bring industry awareness about proper practices for bond breaker application in tilt-up in order to minimize issues and potential detrimental problems to tilt-up projects.

Although neither TCA, nor any other committee directly associated to tilt-up construction, has published a best practices or guide for the application process of bond breaker specifically, it should be noted that the American Concrete Institute (ACI) does provide a few references regarding general concrete construction. The ACI has published several reference manuals including the MNL-15(16) Field Reference Manual. This volume is a compilation of ACI 301-16 *Specifications for Structural Concrete* with additional ACI documents on measuring, mixing, transporting, and placing concrete; concrete pumping methods; hot-and cold-weather concreting; consolidation; and concrete formwork. ACI 301-16 requires that the contractor keep a copy of this manual in the field office of any project where ACI 301 is specified.

The SP-002 (07) *ACI Manual of Concrete Inspection* publication states that this manual is for guidance, assistance, and instruction of concrete inspectors and others engaged in concrete construction, such as field engineers, construction superintendents, supervisors, laboratory, field technicians, inspectors, and workers. From the SP-002 (07) document, Chapter 3 Inspection and Testing of Materials, Chapter 8 Inspection before concreting, and Chapter 15 Special concreting methods are identified as relevant to this report. In Chapter 3, ACI states that materials are to be

inspected and tested to see that they meet contract document requirements and that they should be properly stored, handled, and used in the work. Chapter 3 goes on to clarify that in the application process of bond breaker, testing of the moisture and absorption of aggregates is an important component to the process. ACI further clarifies their reasoning for proper testing of moisture content and absorption of a concrete mixture through an example such as determining the amount of water contributed to, or absorbed from a batch by the aggregates. ACI explains that “an improper adjustment of even 1% in moisture content could increase the slump test as much as 1 inch and decrease the compressive strength of the concrete by as much as 300 psi” (ACI Committee 311, 2007). Performing moisture content and absorption tests incorrectly could also have detrimental effects to a bond breaker’s effectiveness, which is why many bond breaker manufactures also offer guidance on moisture tests in their product data sheets. In Chapter 8 Inspection before Concreting, ACI states that close inspection before placing concrete is important, including checking the proper conditions and preparations. This document offers a description of the necessary preparations with thorough guidance throughout this chapter. For example, moisture preparations, standing puddles of water, and placement of reinforcement, but most relevant to this study proper form tightness and alignment, coating for release agents of forms, and cleanliness. Each section offers a general checklist for proper guidance. In Chapter 15 Special Methods, ACI offers a section specifically for tilt-up construction. Unfortunately, this chapter in the manual contains only supplementary material and just briefly covers the special kinds of concrete work. Additionally, ACI does offer a separate reference at the end of each section in this chapter for further guidance. In the tilt up section ACI states, that “for additional guidance on tilt up construction, refer to ACI 551R” (ACI Committee 311, 2007).

The MNL-15(16) Field Reference Manual includes ACI 301-16 *Specifications for Structural Concrete with selected ACI and ASTM References* publication states that this specification is a reference specification that the engineer or architect can make applicable to any construction project by citing it in the project's specifications manual. The MNL-15 (16) document covers materials and proportioning of concrete; reinforcing and pre-stressed steels; placing, finishing, and curing of concrete; and formwork design and construction. One of the relevant documents in this field reference manual to tilt-up construction and specifically bond breaker for the casting slabs, is ACI 308-16 Standard Practice for Curing Concrete reported by ACI Committee 308 Curing Concrete. This document offers general knowledge about the need for curing, references ASTM standards, and provides methods of curing for different constructions. Even though this standard deals primarily with curing concrete, it also offers insight into common considerations that could affect bond breaker application, including during cold weather and hot weather curing. Additionally, this standard gives criterion for effectiveness of curing and minimum curing requirements. In order for a casting slab to properly interact with the bond breaker, the concrete of the slab needs to have been correctly cured and prepared. The ACI 308-16 document offers some guidance for contractors and engineers in this regard (ACI Committee 301, 2016).

The information discovered from the literature review could be applied as a guide or reference in the bond breaker application process. For example, Engelman's guideline for applying bond breaker outlines a simple general solution for this process. Although the detrimental effects to a project that can occur when bond breaker is incorrectly applied should be fully understood, as the example from Concrete Construction posting and response demonstrates. This report conclusively, recommends that TCA should take a similar approach for the

application process of bond breaker as they did for the new OSHA 1926.1153 regulation involving the glue application process. TCA needs to bring a similar awareness to the industry regarding the practice of bond breaker application for tilt-up construction in order to minimize issues and potential detrimental problems on tilt-up projects.

Chapter 3 - Introduction of Survey

The proper application of bond breaker is a crucial part of the construction process for a tilt-up project. In order to comprehend the industry's current understanding and standard practices of applying bond breaker, an anonymous electronic survey was distributed to tilt-up professionals: members of TCA, ACI, and commercial firms in the Midwest. The online survey platform, Qualtrics, was used to develop and distribute the survey via email during the month of July 2018, and collect responses to the survey which closed at the beginning of August 2018. Throughout the month of July, the survey received a total of 81 responses during its availability. The TCA and ACI organizations were initially contacted to in order to obtain the most applicable audience for this survey. They were asked to distribute the online survey link to any member or other committee, organization, or person that would be interested in this research. Some of the key groups among which the survey was distributed were ACI Committee 551 Tilt-Up Construction, Concrete Promotions Group and TCA. The survey was intended for industry professionals involved with any aspect of tilt-up construction including designers, engineers, contractors, suppliers, educators, architects, developers, and etc. The introduction portion of the survey requested the respondent to identify which aspect best described their involvement in the tilt-up process within their company or organization. This introduction was followed by the main portion of the survey which specifically addressed the bond breaker application.

The survey consisted of 38 questions, formatted as a variety of multiple choice, select all that apply, scaled, and open-ended formatted questions. The survey was divided into four main sections: the consent agreement, demographics/background, the use of bond breakers in tilt-up construction, and the closing statement. The survey opened with an introduction of the overall survey, with the survey developers' contact information and a consent statement to advise the

participants of the use their anonymous answers as data for this research. This was followed by nine questions regarding the participant's role within their company or organization and questions about their general knowledge and involvement in the tilt-up construction process. The main portion of the survey contained a total of 27 questions regarding the use of release agents in concrete tilt-up practice. Specifics including weather considerations, type of release agents commonly used, slab finishing/curing process, general knowledge and typical practices involving release agents were examined. The survey was concluded with a statement of gratitude for participating and an option for the participant to volunteer for further inquiry regarding the subject. A copy of the complete questionnaire is provided in Appendix A – Online Survey. The results from the respondents are used to compare their responses to the guidelines from various manufactures of bond breakers. This comparison has been used to identify knowledge gaps and/or discrepancies in the practices of bond breaker application which is presented in Chapter 5 – Data Analysis.

The analysis of the survey's data has been accomplished by using the data management features provided in the Qualtrics software. These report organized the survey data by each individual question and it shows each respondent's respective answers. Additionally, Qualtrics allows the user to add filters to these reports, filtering the data that is pertinent to the respective analysis. The user can select certain criteria such as specific questions, individual answers, or relevant terms to filter through the entire survey, allowing for ease of result analysis. If the user recognizes a crucial filter or desires to come back to this specific filter at a later time, Qualtrics offers the ability to save the filter or generate a copy of the report with that filter. These Qualtrics filtering features were used extensively in this research. Other features of Qualtrics

used throughout the data review were hiding pages, exporting reports, and results-report visualizations.

Chapter 4 - Survey Results

The survey was available for four weeks and a total of 81 surveys were either fully or partially completed. With a distribution to 500 participants, the survey reached a response rate of 16.2%. This rate can be comparable to an average response rate of 10% to 15% for external surveys (Rattray, 2018). Before proceeding to the analysis of the technical content in Section 3 of the survey, an evaluation of the demographic data was performed using the results from Section 2 of the survey.

After the consent agreement in Section 1 of the survey was fulfilled, Section 2 of the survey respondents were asked nine general questions regarding their demographics, background, overall experience in the tilt-up process, and role within their company or organization. These results conveyed an improved knowledge and experience base of the respondents.

4.1 – Analysis of Demographic and Background Survey Results

4.1.1 – Results for Question 2.1

Figure 1 Description of Company/Organization below, represents the results for Question 2.1, “Which best describes your company?” The groups with the largest rate of response to the survey were the subcontractors accounting for 44% of the survey participants followed by general contractors at 18% of the respondents. Therefore, a majority of the data from this survey represents the perspective of tilt-up installation contractors and field technicians. The survey also reached materials suppliers, engineers, educators and architects, where their participation contributed for 17%, 14%, 5%, and 2% respectively. The survey did not reach any project owners or developers as participants. Question 2.3 is “Using the map provided, what region of the country does your company or organization primarily do tilt-up projects in?”. The response options included, “Outside of the United States”. The map indicating the different regions can be seen in Appendix A.

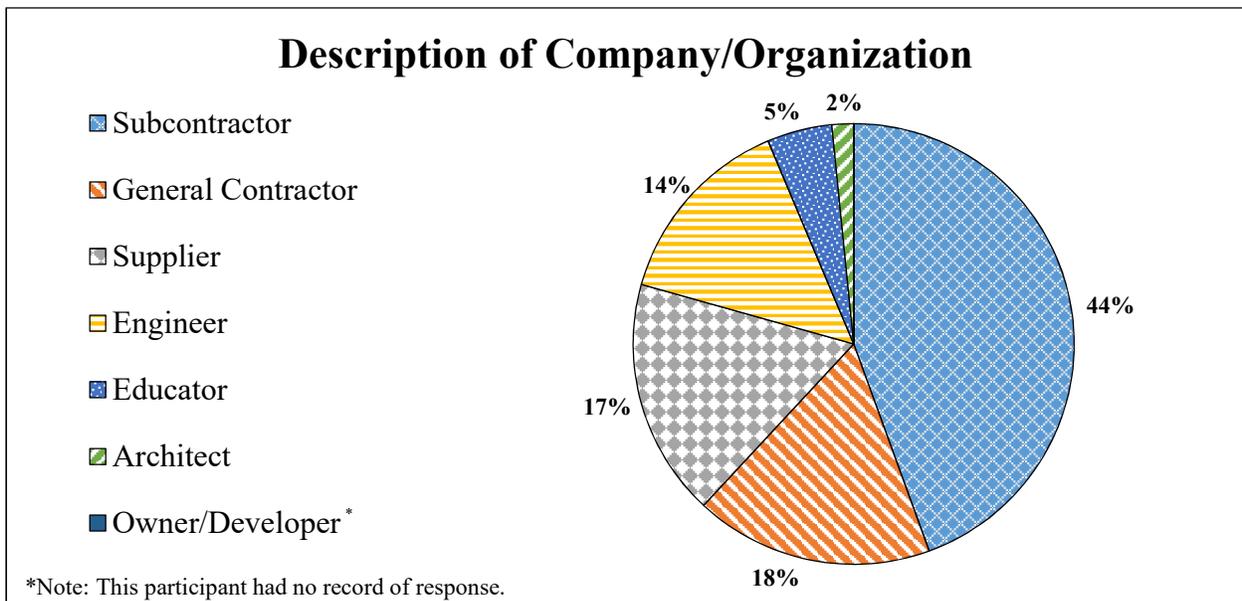


Figure 1 - Description of Company/Organization

4.1.2 – Results for Question 2.2

Figure 2 Region of Tilt-Up Involvement below, represents the data for the respondent's region of tilt-up involvement. The distribution of the survey was predominantly sent to organizations within the *Midwest* and *Southeast* regions. For example, both of the organizations Concrete Promotions Group and the engineering firm of Needham Design Build Steel (DBS) are located in Lenexa, KS. Therefore, the results show that more than half of the participants are from the *Midwest* region and *Southeast* region, contributing 32% and 23% of the participants, respectively. The next two highest regions of tilt-up involvement occurs in, the *West* region and *Outside of the Nation*, with both of these regions each contributing to 18% of the survey's total participants. The remaining two regions, *Northeast* and *Southwest*, contributed less than 10% of the participants combined.

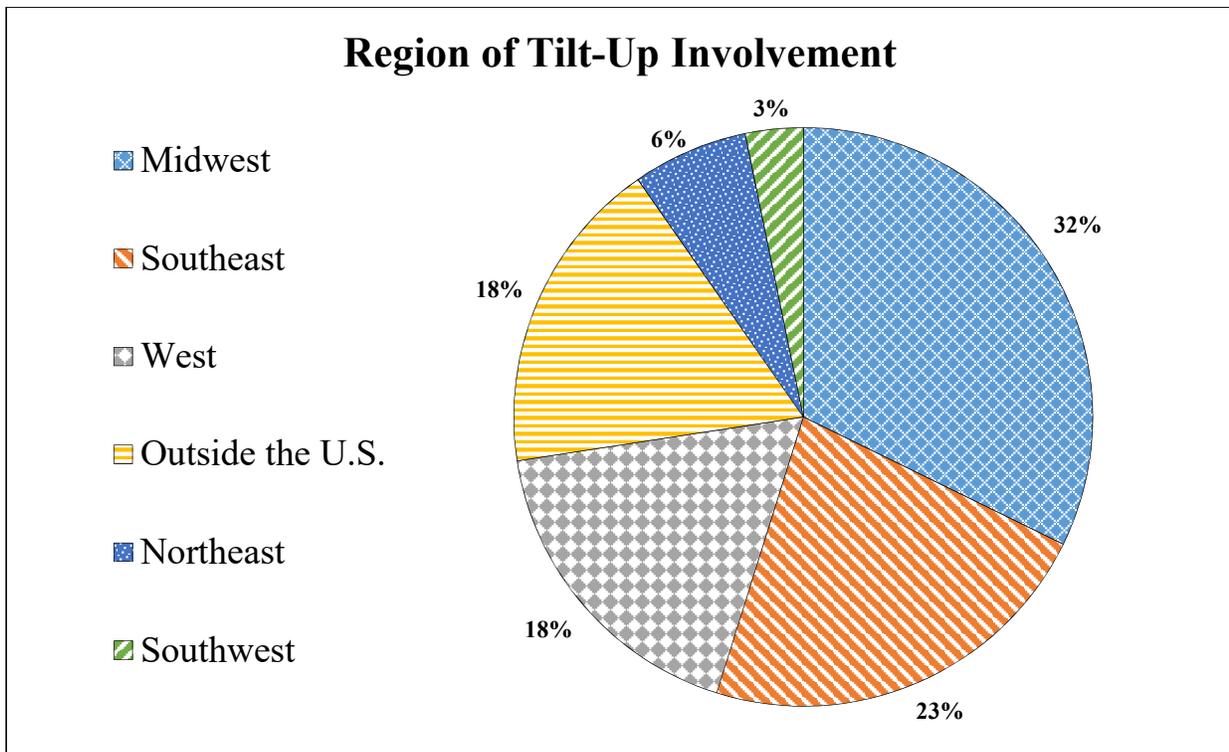


Figure 2 - Region of Tilt-Up Involvement

4.1.3 – Results for Question 2.6

Figure 3 Most Common Tilt-Up Types of Buildings below, indicates the results for Question 2.6, “What typical buildings does your company or organization use tilt-up construction based on its occupancy type?” The survey’s question allowed the respondents to answer this question in a percentage per building type offered using a slide scale of 0 - 100%. The majority of the respondents, 28%, indicated warehouses as the most common building type. Industrial buildings were the second most common building type at 17%. The remaining options ranged between 5% to 10%. These results are not surprising since the majority of the tilt-up construction economy involves these types of building. In a statement by a representative from Bob Moore Construction, “tilt-up provides numerous advantages over traditional construction for warehouses, storage facilities and other types of industrial projects” (Moore, 2016).

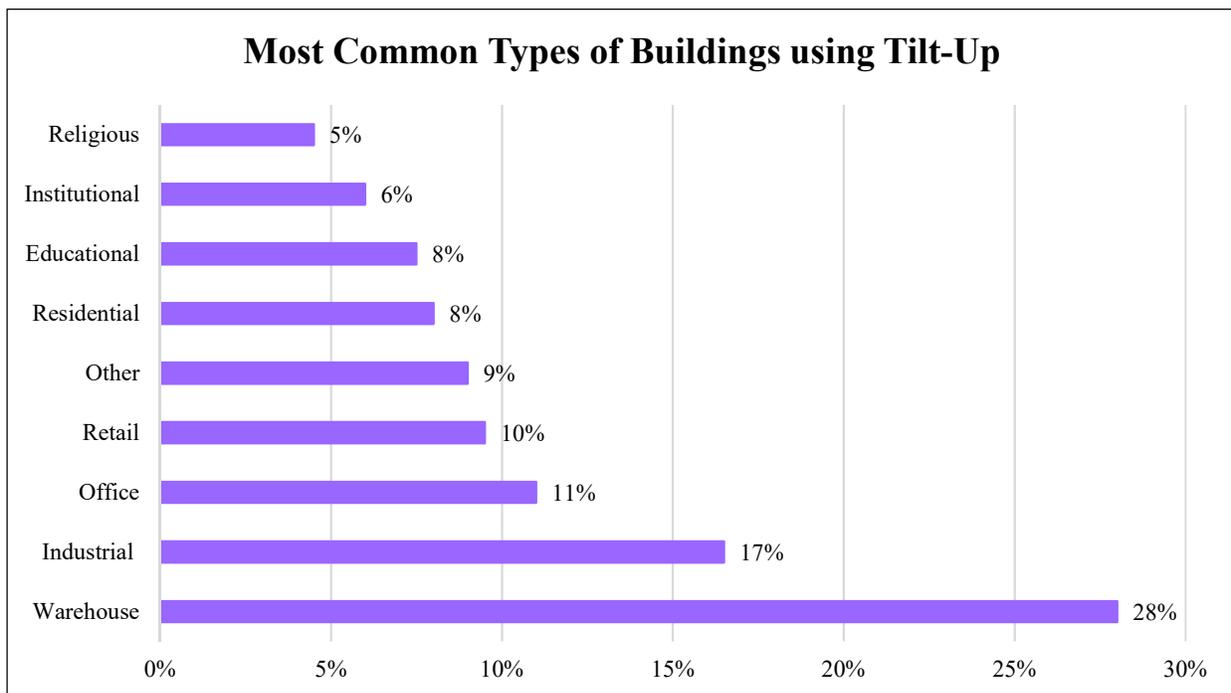


Figure 3 - Most Common Types of Typical Buildings Using Tilt-Up

4.1.4 – Results for Questions 3.3, 3.4 and 3.6

Questions 3.3, 3.4 and 3.6 asked the respondents to identify which type of bond breaker is commonly used by their company or organization based on three characteristics. The first Question 3.3 asked the respondent to “identify which type of bond breaker is commonly used by your company based on its solution type”. Question 3.4 asked the respondent to “specify which bond breaker product your company commonly uses”. Question 3.6 was “what is your company’s preference between chemically and non-chemically active bond breaker?”. These questions were necessary for further data analysis, specifically the details related to the manufacturer used. This information is used for a product data sheet review for each manufacturer and their specific products and used to compare the respondent’s further answers. Figures 4, 5, and 6 below show the distribution of the results for each characteristic of the respondent’s typical bond breaker.

The results in Figure 4 show that 50% of the respondent’s typical bond breaker is water-based followed by 33% selecting solvent-based. The results in Figure 5 show that 75% of the respondents classified their typical bond breaker as chemically active. Figure 6 shows the distribution of typical bond breaker manufacturers used by the respondent’s company, with a majority of 55% using the manufacture Nox-Crete. The four most used manufacturers specified by the respondents are used for the product data sheet analysis, discussed in Chapter 5 – Data Analysis.

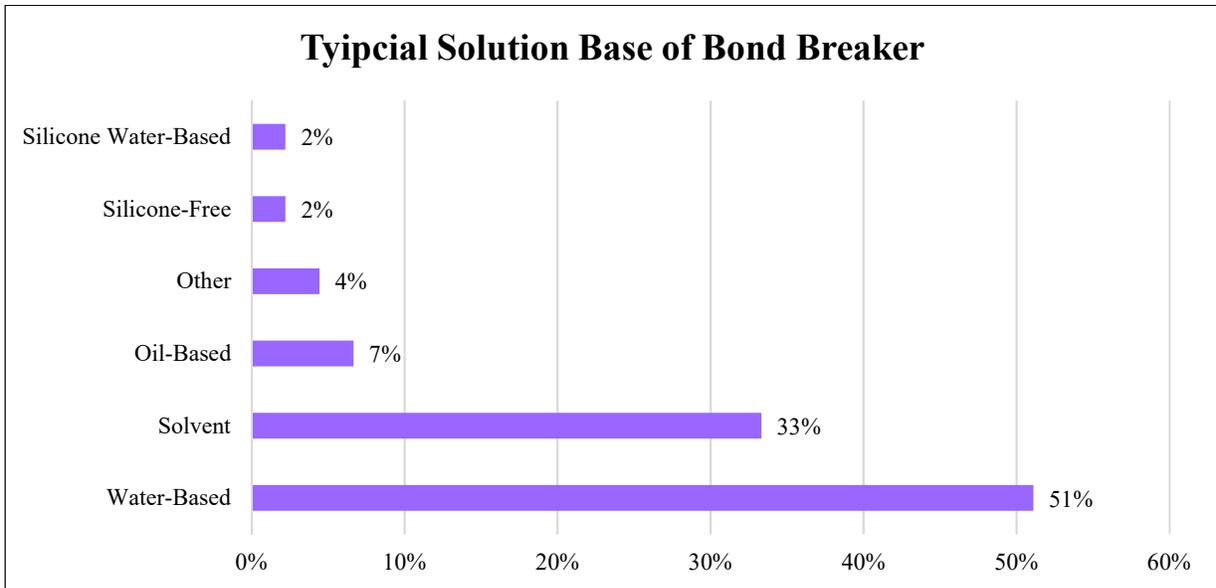


Figure 4 - Typical Solution Base of Bond Breaker

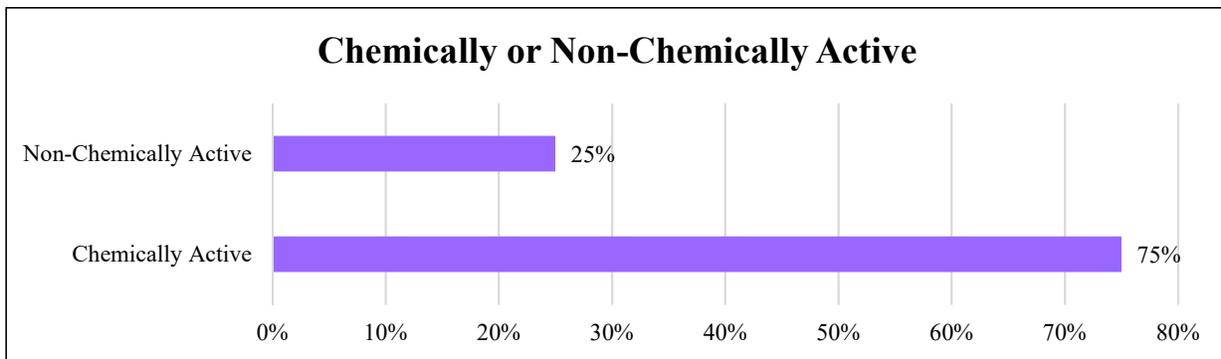


Figure 5 - Chemically or Non-Chemically Active

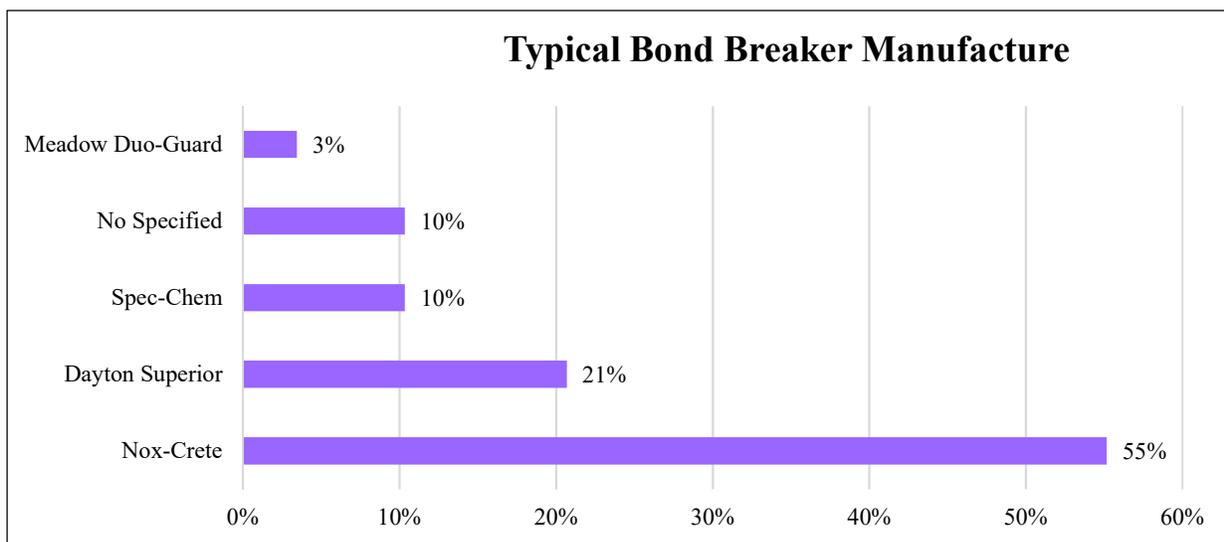


Figure 6 - Typical Bond Breaker Manufacture

After reviewing these demographic and background questions in Section 2 of the survey, several main conclusions can be made about the survey's audience. Foremost, the results from Question 2.1 are significant when reviewing Section 3 of the survey. The results show that over 60% of the participants are contractors or field technicians. Additionally, the results for Question 2.3 also show that the participants are involved with tilt-up projects predominantly in either the Midwest or Southeast regions of the United States. These conclusions from Section 2 of the survey will carry over into Chapter 5 – Data Analysis and in the analysis of Section 3 of the survey.

Chapter 5 - Data Analysis

The main portion of the survey Section 3 “The use of bond breakers in tilt-up construction” consists of 22 questions covering the practices of concrete tilt-up design and construction with a focus on the preparation of the slab and formwork that the concrete panel will interact with. These questions primarily asked the participants to explain their typical practices during the construction process and how their company or organization handles different situations and unforeseen conditions. For example, some of the questions regarding the construction process ask how the participant’s typical practices would be adjusted based on weather related issues. A copy of the entire survey can be found in Appendix A – Online Survey.

As previously stated, the results from the entire survey could lead to a variety of conclusions and potential insights into other concerns and issues involving bond breakers. Despite these other avenues of potential useful investigation, it was decided instead to focus this research specifically on five questions and their responses from Section 3 of the survey. A copy of the following five “Survey Questions of Interest” can be seen below in Table 2. These five questions and their overall results will be analyzed in a similar manner as the questions presented in Chapter 4 – Survey Results. The only additional analysis for these questions is the breakdown of the results between each type of participant. For a majority of the questions in Section 3, the participants were provided three to four potential answers, additionally offering an “Other: Please Specify” response option. The results from Question 2.1 asking the participant, “what best describes your company?” will be used to categorize them. It should be noted that the results from Question 3.4 which specify the typical products used by the participants will be analyzed last, which will then lead to the product data sheet study.

Table 2 - Questions of Interest

Survey Questions of Interest		
No.	Question	Options
3.1	What specific weather related issues affect your method of slab preparation before applying a bond breaker?	High Humidity / Recent Precipitation / High Winds / Other: Please Specify
3.2	What changes are taken into consideration in your typical practice when these climate issues are impacting the site? Select all that apply and explain the changes.	Method of Application / Coats of Application / Type of Bond Breaker / Other: Please Specify
3.4	Specify which bond breaker product your company commonly uses?	Please Specify
3.12	Does the ambient temperature have an effect on the application of bond breaker?	Yes / No
3.13	Based on the previous question, what considerations are taken? Please explain your answer.	Method of Application / Coats of Application / Time of Application / Other: Please Specify

5.1 – Analysis of Bond Breaker Application Survey Results

5.1.1 – Results for Question 3.1

The results are shown below in Figure 7 Weather Related Issues for Question 3.1 asking the participants, “what specific weather related issues affects your method of slab preparation before applying a bond breaker?” This question had one of the highest response rates at a total of 61 responses, which equates to 76% of all participants. After reviewing the results from the “Other: Please Specify” option, the majority of participants who indicated other, all had a similar answer, stating “Cold/Freezing Temperatures”. Therefore, this option has been added to the overall results as shown below in Figure 7.

The results show that the option “Recent Precipitation” was the highest selected option out of the four, with a total of 27 (45%) of the participants choosing this option. This option was followed by “High Humidity” and then “High Winds” as the next highest two options with a total of 15 and 12 responses respectively. Lastly followed by the new option “Cold Temperatures” with 7 responses. Reassessing the results by participant type, it was noted that the option with the highest rate of response for three of the types of participants was “Recent Precipitation”, These three groups include subcontractors, general contractors, and suppliers. The three participants who are categorized as engineers each answered this question differently and their responses were between the three options of “High Humidity”, “Recent Precipitation”, and “High Winds”. Another notable conclusion that recurs throughout this survey is the drastically low response rate of three types of participants which includes engineers, educators, and architects. Despite the three engineers and two educators who did respond to this question, their response rates for the following questions will decrease or in some results these groups had no

recorded responses. The results from this question will be used for further analysis and discussion later in this chapter.

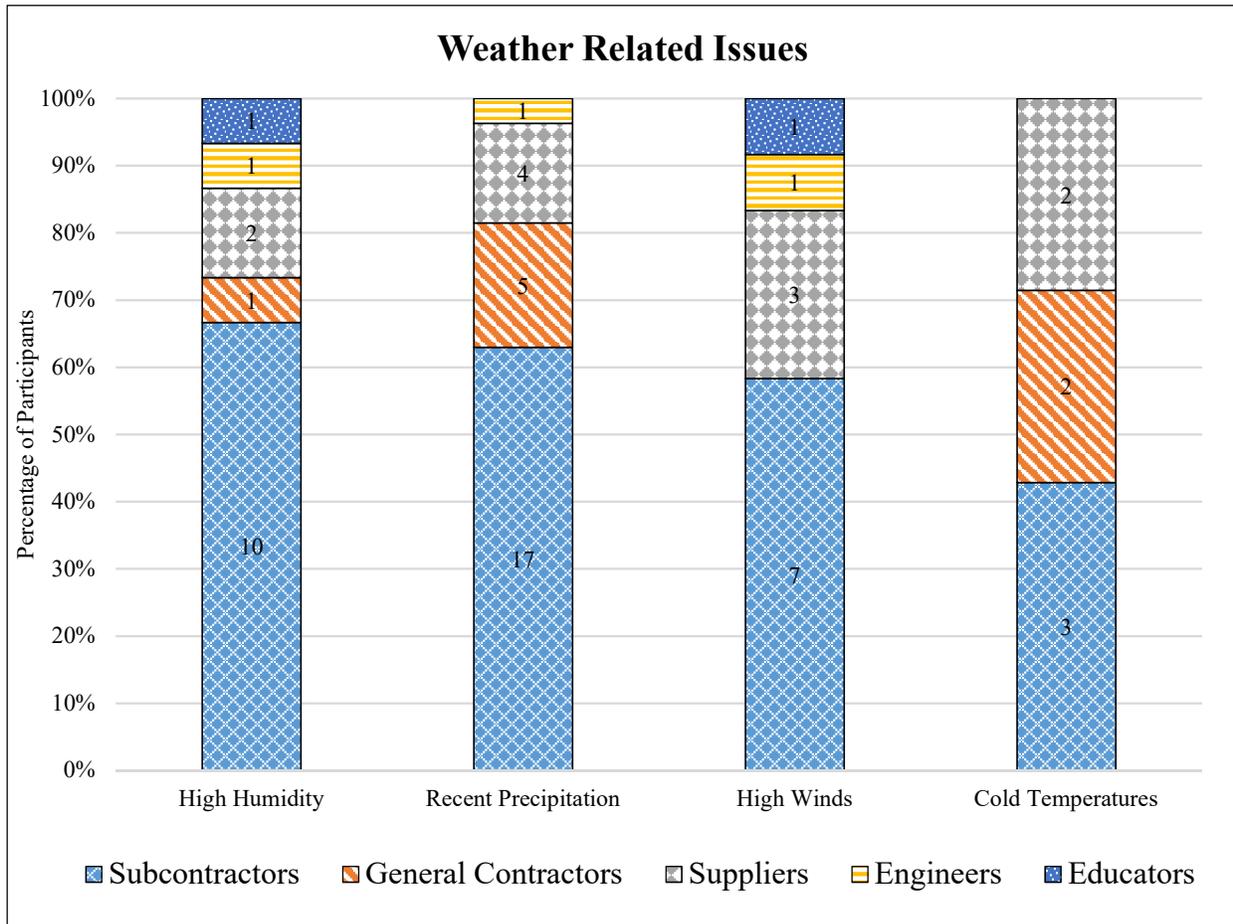


Figure 7 - Weather Related Issues

5.1.2 - Results for Question 3.2

The next question of interest, 3.2, asked the participants for a follow up response to their response in Question 3.1, asking them, “What changes are taken into consideration in your typical practice when these climate issues are impacting the site?” The results for Question 3.2 are shown below in Figure 8 Changes to Typical Practice Due to Weather Related Issues.

The three types of changes that were offered to the participants included “Method of Spray Application”, “Coats of Application”, “Type of Bond Breaker”, and a “Other: Please Specify” option was again offered. This question allowed for the participants to select all that apply and asked them to explain their changes. It should be noted that not all of the participants explained their answer. Following the same analysis procedure as the previous question, the results from the option “Other: Please Specify” show that all five of the participants that selected this option provided an answer involving a change of time for the product’s application. For example, some of the responses stated, “allow the casting slab to dry before application”, “alter the time of the day we install the bond breaker”, and “timing”. Therefore, the option “Time of Application” will be included in the results for Question 3.2 as shown above in Figure 8.

The results from Question 3.2 show that changes to the “Method of Application” and “Type of Bond Breaker” were the two most common options when weather related issues are impacting the site. These two options together accounted for 38 (72%) of the 47 total responses. 20 participants (43%) stated they would alter their “Method of Application” and 14 (30%) stated they would change their “Type of Bond Breaker”. Out of the first group of 20 respondents there were 10 participants who also provided further explanations. After reviewing these 10 explanations there were two groups of explanations provided for the option “Method of Application”. Six of the participants stated that they would have to reapply the bond breaker or apply a thicker or heavier initial coat. The next group of 3 participants stated that they would change their physical method of application to a combination of “spray and then back roll on” or they would instead use a power sprayer instead. In addition of these two prominent groups, the results did show a small group of participant stating that they would apply a “lighter initial coat”. The result from this last group are surprising, this is due to the notable contradiction between this

group and the first group of changes. The first group stated they would either reapply the bond breaker or apply a heavier or thicker first coat while this group stated that they would apply a lighter coat. The option of reducing the coating amount of bond breaker seems very atypical in this practice and will be compared in the product data sheet study discussed later in this chapter.

The results from the “Type of Bond Breaker” option and its respective explanations were simplified into two groups. One of group of respondents stated that they would change the whole product but unfortunately did not specify what product they would be using initially. Therefore, this group of participants did not provide any further conclusion. On the other hand, the second group of respondents stated they would change their product in regards to its chemical solution base. All of the respondents from this group explained that they would change their product from “water to solvent-based” or vice versa depending on the situation. This change of chemical base could be used for situations where freezing temperatures could impact the site. For example, as stated by Dayton Superior on their “Guide to Tilt-Up Bond Breakers,” one of their solvent based products “Sure Lift with Dye J6D” is categories as not freezable compared to the other two water based products listed on this guide as freezable (Dayton Superior, 2016).

Further breakdown of the results from Question 3.2 can be seen below in Figure 8, visually representing which type of participant selected each option. The educators and suppliers distributed their answers relatively evenly amongst all the options provided, not showing a conclusive choice. In contrast, the subcontractors and general contractors each had a prominent answer. The results show 58% of the subcontractors selected they would change their method of application. However, the results show that 63% of the general contractors stated that they would change their type of bond breaker. This conflict of opinion could be due to different past

experiences and practices which these two groups have had. It was noted that the overall results from this question again show a lack of participant from the architects that took this survey. This observation potentially shows that this group does not have any input on this aspect of the tilt-up process, nor would they want to be liable for this.

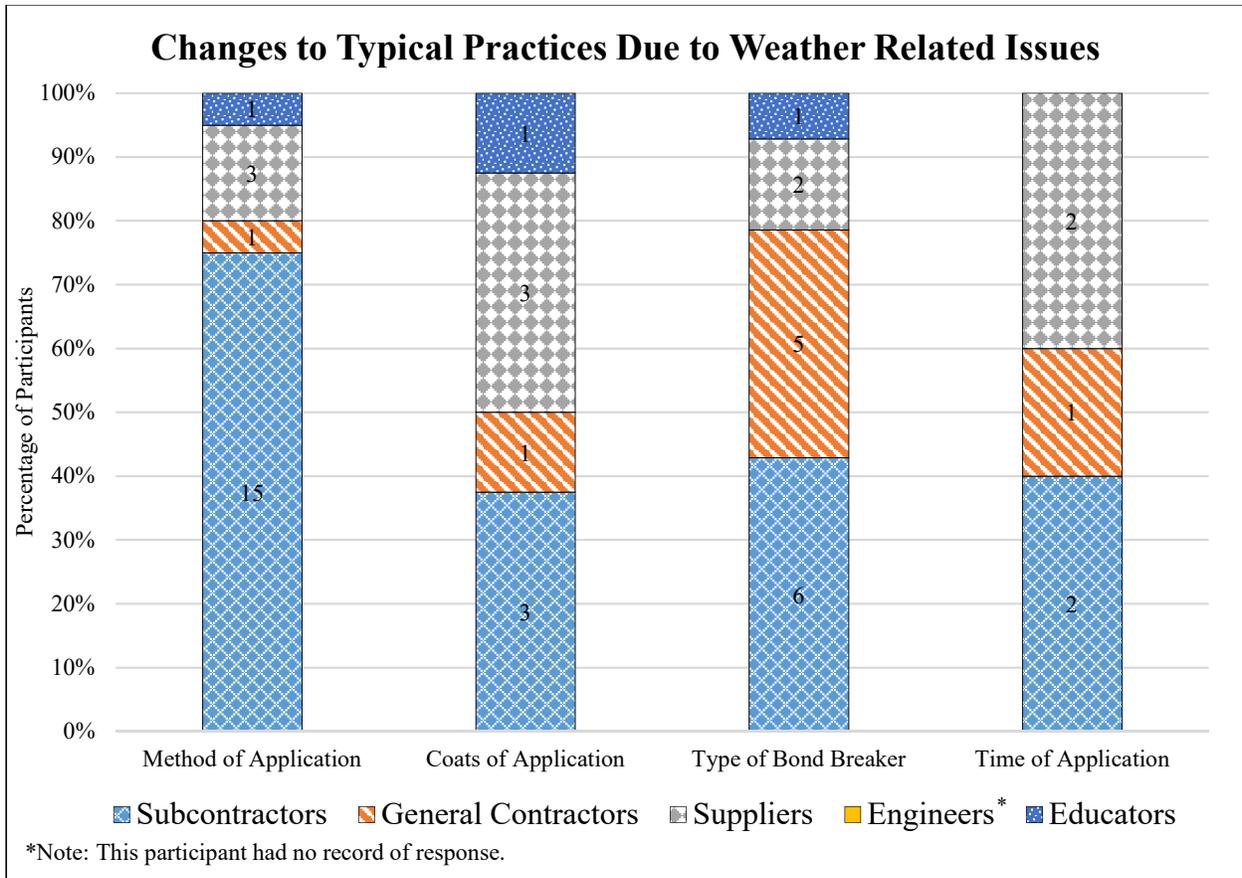


Figure 8 - Changes to Typical Practice Due to Weather Related Issues

5.1.3 - Results for Question 3.12

The next two questions of interest are regarding ambient temperature conditions during the application process. Question 3.12 asks the participants if, “the ambient temperature has an effect on their application method?” This question allowed the respondents to answer with a

simple “Yes or No”. The results for Question 3.12 can be seen above in Figure 9 Ambient Temperature.

A total of 31 participants responded to this question, which equates to 39% of all participants. The option “Yes” accounting for 84% of the participants. Although the results for that option’s response rate are not surprising, a total of 5 (16%) participants still stated that the conditions of ambient temperature do not affect their application method.

Separating the results by the type of participant a majority of all the groups stated that “Yes” the ambient temperature does affect their method of application. 19 out of the 21 total subcontractors that responded to this question selected “Yes”, furthermore all the suppliers and educators that accounted for 13% of the total respondents shared this same perspective. Although it should be noted that the group of general contractors as a whole did not all share the same response. The results from this group of six general contractors were divided equally between both options, not showing a conclusive choice. This indecisive opinion among the general contractors could again be due to the variety of past experiences that each general contractor has had over this issue.

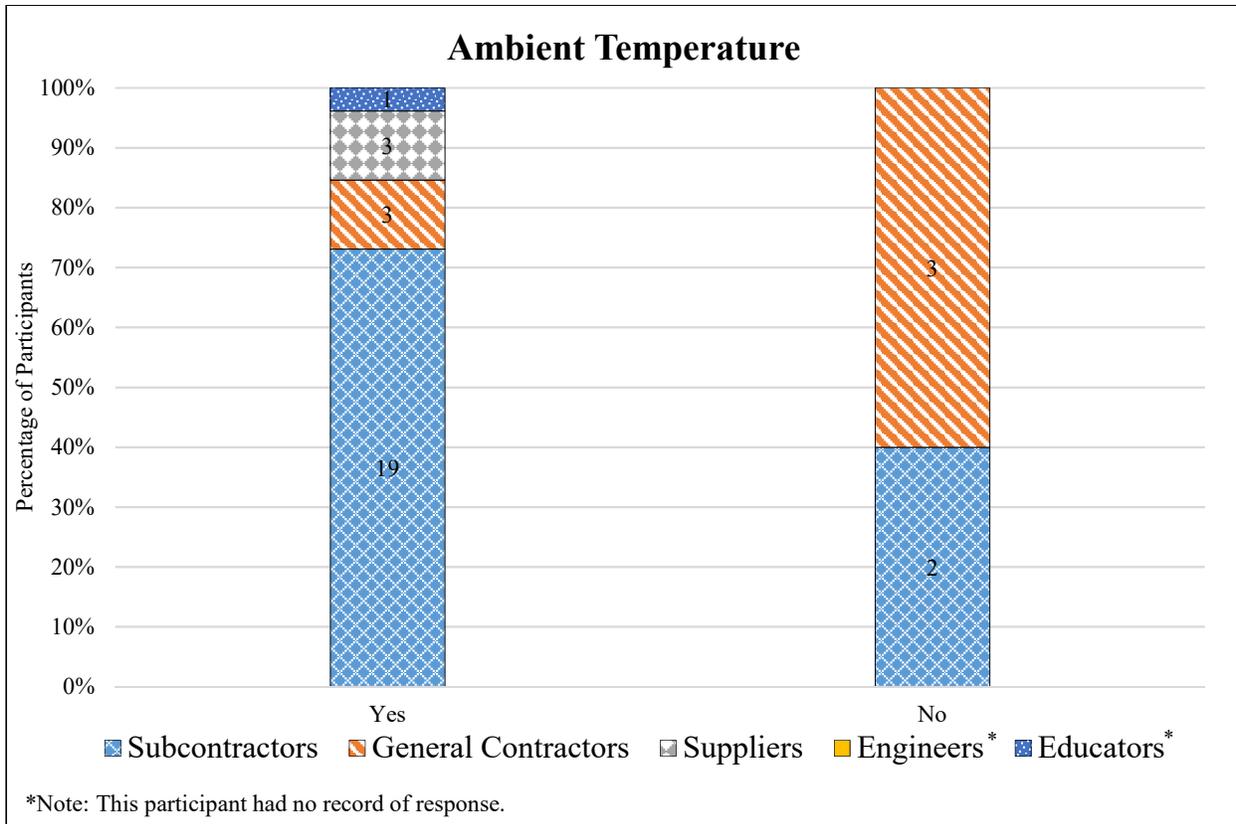


Figure 9 - Ambient Temperature

5.1.4 - Results for Question 3.13

The next Question 3.13 asked the participants for a follow up response to their choice in Question 3.12, asking them, “based on the previous question, what considerations are taken?” The results for Question 3.13 are shown below in Figure 10 Change Due to Ambient Temperature. Similar to the format of Question 3.2, the survey offered three typical types of consideration that could affect their application process. These options included “Method of Application”, “Coats of Application”, and “Time of Application”, the option of “Other: Please Specify” was also offered. This question allowed the participants to select all that apply and asked them to explain their selection. It should be noted that not all of the participants explained their selection.

A total of 60 responses were submitted amongst the three options. The results show that all three of the changes involving method, coats, and time of application were nearly evenly selected. The option with the overall highest response rate was “Coats of Application” with 22 (37%) responses, followed by “Method of Application” accounting for 20 (33%), and then lastly “Time of Application” was selected by a total 18 (30%) respondents. The format of this question allowed for the participants to further explain their selected answer.

Following the same process of analysis as the previous questions, the results from the “Other: Please Specify” show that all three of the respondents that selected this option specified an answer involving changes to their method of application. For example, two out of those three participants stated that they would “initially spray and then back roll” as needed, and the third responses vaguely stated they would change from their application type from spray on applicator to another method as needed per the ambient temperature. Therefore, the no additional option was included into the results for Question 3.13 as shown in Figure 10 below, and those three participants were included into the “Method of Application” results.

Starting with the results from “Coats of Application”, this option had three prominent groups of explanations for their changes. Two groups defined their changes based on a specific weather consideration. The first group of participants stated that in “hot or humid” temperatures, they would apply more coats. Two of these respondents further explained their thought process with one stating, “the hotter the temperature, the deeper the bond breaker gets absorbed, so more coats should be applied” and the other stated that, “during summer months, more coats are required due to ultra violet waves breaking down the product”. On the other hand, the next group of respondents elaborated their changes with the consideration of “cooler or freezing” temperatures. An example of a common response for this group was, “the cooler the ambient

temperatures, the thinner the coats should be applied”. The last group from these results, which accounted for only three participants simply stated that their changes would, “follow the manufactures recommendations”. In regards to liability, this group of participants provided what would be considered the most accurate answer. The results from the “Method of Application” all had similar explanations, stating that their changes would involve switching or combining the use of different types of applicators. As previously stated, a majority of the responses stated that they would spray the product then provide a back roll. Followed by the results from the option “Time of Application”, these responses could be divided into two different groups each considering a specific type of ambient temperature. One group stated that their time of application would be adjusted to as early as possible to allow for adequate drying, while the other group stated that the time of application would be adjusted to as close to the concrete pouring as possible to eliminate the evaporation rate. The first group of responses were related to cooler ambient temperatures, while the second group was related to hot and humid ambient temperatures. These results will be used in further discussion and compared later in this chapter with the product data sheet summary.

Further breakdown of the results from Question 3.13 can be seen below in Figure 10, which shows the distribution of respondents based on the type of participant. Although comparing the results from this question to Question 3.2, there was not a single group of participants that showed a preference between these three options. This includes the subcontractors, general contractors, suppliers, and educators. Each group was almost evenly distributed between each option. The same conclusion regarding the participant of the architects can be made with these results.

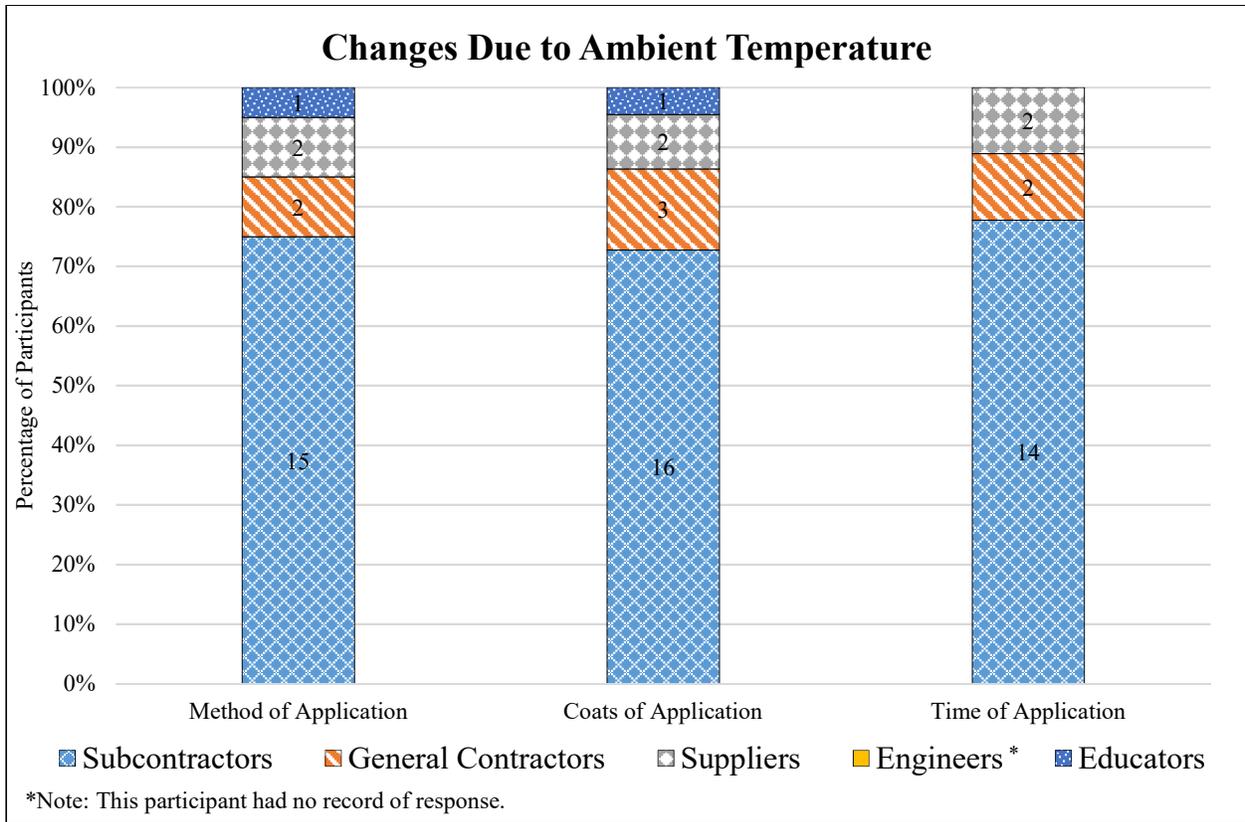


Figure 10 - Changes Due to Ambient Temperature

5.1.5 - Results for Question 3.4

Question 3.4 asked the participant to, “specify which bond breaker product their company commonly uses?” The general results for this question and the two supplement Questions 3.3 and 3.6 have already been analyzed and discussed in Chapter 4 – Survey Results. Although as seen in Figure 11 below, the results from Question 3.4 are now represented in a manner similar to the other questions of interest in this chapter.

A further breakdown of these results shows that a total of 28 (35%) participants answered this question. Two of these participants did not provide sufficient information and were classified as “Not Specified” as shown in Figure 9. After filtering through the remaining 26 respondents, it was noted that four manufacturers were prominent: Nox-Crete, Dayton Superior,

SpecChem, and Meadow Duo-Guard. The supplier Nox-Crete was the most common bond breaker in the group with a total of 15 (54%) participants specifying their products. Dayton Superior was the next most common supplier with six (22%) respondents specifying their products, followed up by SpecChem with four (15%), and then Meadow Duo-Guard with one (4%) participant specifying their product. Evaluating the results amongst the different types of participants, the only group that had a drastic preference in manufacture were the subcontractors. The only other groups that responded to this question were the general contractors and suppliers. The results from these two groups were divided evenly between all of the manufacturers, showing no preference. It should be noted once again that the lack of responses from both the engineers and architects was present in this question. The lack of responses may be due to the same reason that was concluded in the previous analysis of Question 3.2, which is that neither group has an influence on this aspect of the tilt-up process nor do these professionals wish to take on liability for this decision. This question did ask the participants to specify not only their typical supplier, but also specify the product by name that they commonly use at their company or organization.

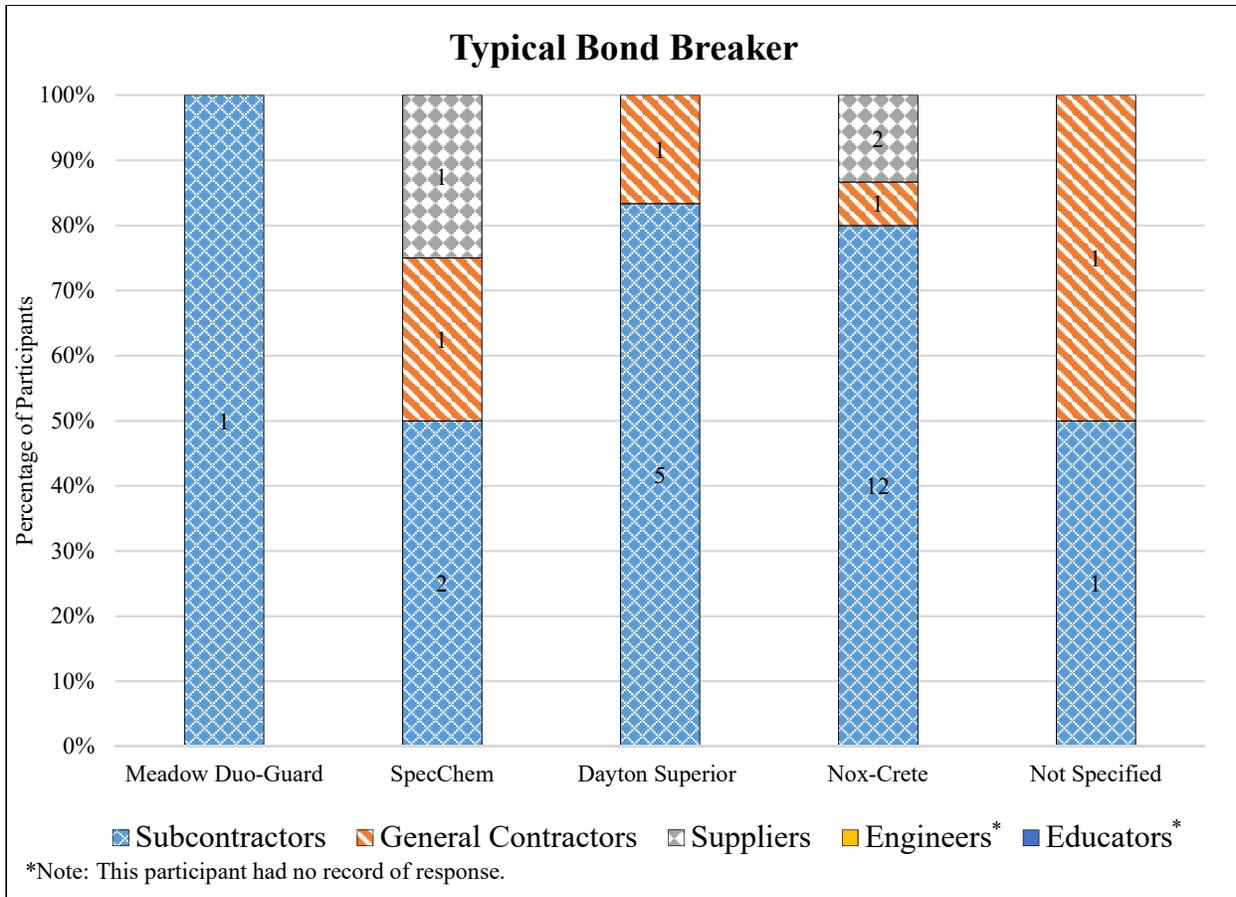


Figure 11 - Typical Bond Breaker

After reviewing all the results for the five questions of interest it was noted that a potential connect could be made between the information from Question 3.4 and the results from Questions 3.1, 3.2, 3.12, and 3.13. The information provided from Question 3.4 that will be crucial in this comparison is the names of the products that were specified by each participant. Each product has a respective technical product data sheet that is provided by the manufacturer and these documents offer information and guidance that can be related to each question of interest. This connection, therefore, led to an in depth study of the manufacturers' technical product data sheets.

As seen previously in Chapter 4 – Survey Results, the results from Questions 3.3, 3.4, and 3.6 show a general three question breakdown of the typical bond breaker that the participants have used or specified for their company or organization. The main question of interest out of these three was Question 3.4 asking the participant to, “specify which bond breaker product your company commonly uses?” The results from this question revealed a variety of products, a majority of the participants specified the product name of the bond breaker while a few only named the manufacturer. Two participants answered this question with insufficient information and will be disregarded from the data. After filtering through all the responses, six different products were identified. From the supplier Nox-Crete the three products that were listed were Silco Seal Select, Silco Seal 2000F, and Silco Seal Classic. The two products from Dayton Superior that were specified were Sure Lift J6WB and Maxi Tilt. Followed by the least common manufacturer SpecChem, the single product that was specified from this supplier was SpecTilt 100. The fourth manufacturer from the results, Meadow Duo-Guard, unfortunately was not specified with a product name, therefore that manufacturer will not be included in this portion of the analysis.

5.2 –Analysis of Manufacturer Product Data Sheets

Research was then started for each of these six individual product. This was done by finding the products technical product data sheets from their respective manufacturer's website. Each manufacturer is required to provide a product data sheet with each product. A product data sheet, commonly known as spec sheet, is a document that summaries the performance and other technical characteristics of a product. There should be enough details to allow designers or users to understand the role of the component in the overall system. These sheets should be provided as an introductory description of the product. All individuals involved in the selection and application of the product should be familiar with the product data sheets. Based on some of the survey's responses, it is possible that the information is not being disseminated to all necessary parties. This is where miscommunication and lack of knowledge of the specific product could interfere with the outcome of the results. In this case, where the bond breaker is misused or incorrectly applied could negatively affect the lifting process of the concrete panel and the overall project success.

After collecting and reviewing the product technical data sheets for all six of the bond breakers, each manufacturer provides a typical format and breakdown of their product. The document typically begins with a product description, but since these sheets are specifically for bond breakers the majority of the content revolves around their general application process and then followed by precautionary and legal information. Some of the additional information provided in these documents that will not be covered in this research include storage and handling recommendations. Each manufacturer covers a variety of different situations and issues that could be considered during the application process. The main focus for this study will include the provided information about surface preparation, moisture retention properties,

application rate, drying time, application test, and three weather considerations (heat, precipitation, and cold). It was decided to focus on these specific subtopics for the research because these topics are directly related to the survey's questions reviewed previously in this chapter.

The results from the Product Data Sheet Summary can be viewed below in Tables 3 and 4. Two tables were developed from this research; one table includes the result for the two products from Dayton Superior along with the single product from SpecChem and the second table summarizes the results for the three products from Nox-Crete. The tables were divided up in this manner for organization and ease of communication. The results for each product include the breakdown of the eight subtopics that were previously stated regarding the different considerations during the application and construction process. In addition to those subtopics, the tabulated results also include the type of bond breaker. They are all characterized by their chemical solution base (water or solvent), and if they are chemically active or not.

These tables were also organized in a manner where the product data sheets provide similar information for multiple products whose respective columns were combined into one cell with that shared information. For example, all six products share the same information for "Moisture Retention Properties", stating that the casting concrete surface which will have the bond breaker applied to must meet ASTM C-309, when applied to a steel troweled finish surface. It was noted that for the products from the same manufacturer they typically shared the same information for each subtopic. The product data sheets from the supplier Nox-Crete are a seamless example, the manufacturer provides consistent information for all three of the products that were studied. This consistency allows for an ease of comprehension for the manufacturer's products, for example this could be beneficial for a field technician using Nox-Crete's bond

breaker products because they will not have to read and understand how to use a whole new product data sheet if the product changes from Nox-Crete's SilcoSeal 2000F to SilcoSeal Select or SilcoSeal Classic. The reason why Nox-Crete is being used for this conclusion is because a total of three products were used for this study which accounted for more than the other two individual manufacturers.

This consistency was found amongst each of the three individual manufacturer's product data sheets. Although when comparing different manufacturer's product data sheets, it was found that some supplier's lacked information in areas that others would provide. The next few comparative studies will show some of the distinct differences that were found from the results, but are not limited to only these. For example, both Dayton Superior and SpecChem state that they recommend using their product with a "low-pressure pump-up sprayer" while Nox-Crete did not provide any information or recommendation for how their product should be used. Another example of lack of specific information can be seen in the subtopic of "drying time". Once again, both suppliers Dayton Superior and SpecChem specify in their product data sheets that their recommended drying time is approximately 2 hours but also stated at a temperature of 70° F (21° C). On the other hand, the data sheets from Nox-Crete for all three of their products only state that their recommended drying time is typically 30 minutes to 3 hours. The information for this subtopic from Nox-Crete not only lacks the specific climate conditions that the other two provide but also give a wide range for their drying time. Another subtopic of interest after reviewing the results was within the "application rate", specifically comparing the physical square footage per gallon rate that the manufacturer recommends for their products. Results from all three of the product data sheets from Nox-Crete only show that they recommend a "typical effective coverage rate is 200 – 400 square feet per gallon". However, both Dayton

Superior and SpecChem state not only a single typical application coverage rate but both suppliers recommend a coverage rate for the first coat and second coat of product. These inconsistencies between the supplier's and the information provided in their product data sheets could be due to past experiences and issues that these manufacturers have encountered. Issues related to use of their products leads to the supplier's having to purposely change or even remove some recommendations and guidance in their product data sheets.

Table 3 – Dayton Superior and SpecChem Product Data Sheet Summary

Product Data Sheet Summary			
	Dayton Superior		SpecChem
	Sure Lift J6WB*	Maxi Tilt*	SpecTilt 100*
Type of Bond Breaker	Water Based - Chemically Active	Water Based - Chemically Active	Solvent Based - Chemically Active
Surface Preparation	Casting slab areas should be well cured, smooth, and dense. Remove all dust, dirt, saw cut residue, standing water and other contaminants prior to applying.		
Moisture Retention Properties	Meeting ASTM C-309, when applied to a steel troweled surface.		
Application Rate	1st Coat: 400 SQ/Gal, 2nd Coat: 550 - 700 SQ/Gal.		1st Coat: 400 SQ/Gal, 2nd Coat: 500 - 700 SQ/Gal.
	Low-pressure pump-up sprayer.		
	Prior to steel placement and within 2 weeks of pouring panels.		
	Applied at right angles (perpendicular) to each other.		
Drying Time	Approximately 2 hours at 70°F (21°C).		
	Cooler temp., higher humidity, and thicker coats will extend the dry time.		
Bond Breaker Test	Sprinkle water on the casting bed, water should bead up. Dried material should have a soap like feel uniformly over the substrate.		
	Extremely porous or otherwise absorptive slabs can also be fogged with water.	Fog the entire slab with water prior to pouring.	
Hot Weather Considerations	Casting slab must be flooded with water to reduce its porosity and cool it down prior to first application.	Apply cure coat immediately after final finish and prior to joint cutting. Before application, saturate the slab surface with water.	
Raining/ Precipitation Considerations	Do not apply in rain or if rain is in the forecast within 12 hours of the application.		
	Rain occurring prior to product drying will necessitate reapplication of bond breaker.		
Cold Weather Considerations	Do not apply below 40°F (4°C) or when ambient temperatures are expected to fall below 40°F (4°C) within 12 hours of application.		

*Note: Information from Table 3 is from the product data sheets for each respective manufacturer.

Table 4 – Nox-Crete Product Data Sheet Summary

Product Data Sheet Summary			
	Nox-Crete		
	SilcoSeal Select*	SilcoSeal 2000F*	SilcoSeal Classic*
Type of Bond Breaker	Water Based - Chemically Active		Solvent Based - Chemically Active
Surface Preparation	Casting slab areas should be well cured, smooth, and dense. Remove all dust, dirt, saw cut residue, standing water and other contaminants prior to applying. Do not pressure wash the surface.		
Moisture Retention Properties	Meeting ASTM C-309, when applied to a steel troweled surface.		
Application Rate	Typical effective coverage rate is 200 - 400 SF/Gal. No more than a 2 weeks delay between the final coat and concrete pouring. Applied at right angles (perpendicular) to each other.		
Drying Time	Typically 30 minutes to 3 hours. Extended drying times in excess of 24 hours are possible when applied heavily in cool weather and moisture barrier is present.		
Bond Breaker Test	Sprinkle water on the casting bed, water should bead up. Dried material should have a soap like feel uniformly over the substrate.		
Hot Weather Considerations	The number of coats and related application rate to achieve complete, uniform coverage of casting slab varies with concrete mix design, placing and finishing procedures, weather conditions, etc. Because of this, it is not possible to prescribe application rates or procedures inclusive of all site variables.		
Raining/Precipitation Considerations	Do not apply in rain or if rain is in the forecast within 12 hours of the application. Rain occurring prior to product drying will necessitate reapplication of bond breaker.		
Cold Weather Considerations	Do not apply below 40°F (4°C) or when ambient temperatures are expected to fall below 40°F (4°C) within 12 hours of application.		

*Note: Information from Table 4 is from the product data sheets for each respective manufacturer.

The results from this study show how important and applicable the use of these product data sheets could be during the bond breaker application process of the construction phase. Based on the information gathered from this survey a further analysis is required to evaluate if the product data information is accurately being used during installation. Comparing the results from the product data sheets to the data provided from the questions of interest may provide additional information.

5.3 – Comparison of Product Data and Survey Results

The following is an analysis of the results from the product data sheet study and the responses from the questions of interest introduced in 5.1 of this chapter side by side for comparison. The information on these tables is separated among the different subtopics that were both addressed in the product data sheet studies and the questions of interest. As previously stated, each subtopic that was reviewed in the product data sheet study can be related back to a question of interest. Question 3.1 presented four different weather considerations which include high humidity/temperatures, recent precipitation, cold/freezing temperatures, and high winds. Following that, Question 3.2 asked the participant to elaborate on their changes to their typical practices of bond breaker application due to the weather consideration that they stated. The responses from these two questions were then further organized between the different manufacturers that each participant specified they typically use. This organization allowed for an appropriate comparison between the manufacturer's recommendations for each subtopic and the participants' respective responses. It should be noted that the product data sheet study provided insight into other subtopics that will not be discussed further in this analysis such as bond breaker testing and moisture retention properties. The comparison of all the subtopics can be found in Appendix B – Chapter 5 Results. For Tables 5 and 6 each type of participant was abbreviated

due to the limitations of space. The abbreviation can be followed as such: general contractors (GC), subcontractors (SUB), suppliers (SUPP), engineers (ENGG), and educators (ED). Each individual response was recorded and tallied with their respect weather consideration and response within their specified manufacturer.

The responses from the questions of interest were simplified and numerically organized next to each of their respective weather consideration within these tables. Each weather subtopic provides a response with a label of “0.)”, this response is the recommendation from the manufacturer’s respective product data sheet for that subtopic, then followed by the participants’ responses starting with the numerical label of “1.)”, then “2.)” and so forth.

The results from the product data sheet analysis resulted in Tables 3 and 4 which include three different manufacturer’s recommendations, therefore three separate tables were developed for comparison. A copy of the three tabulated results can be found in Appendix B. As previously stated, each manufacturer had a different rate of response which will directly affect the quantity of tallied responses for each respective manufacturer. Nox-Crete and Dayton Superior had the two highest rate of response at 36% and 12% respectively and their results provided sufficient information for analysis therefore their results will be used for comparison and further discussion. On the other hand, the quantity of results from the participants who specified SpecChem was not sufficient enough to make conclusive comparisons and will be omitted from this discussion.

5.3.1 – Nox-Crete Results

The results from Table 5 below, show the results from the participants who specified that their typical bond breaker manufacturer as Nox-Crete, along with the respective recommendations from the manufacturer’s product data sheets. The results from the three

subtopics “High Humidity/Temperatures”, “Recent Precipitation”, and “Cold/Freezing Temperatures” compared to the manufacturer’s recommendation show an inconsistency between each type of participants.

First, it was noted that the manufacturer Nox-Crete does not have any specific guidance over the subtopic regarding high humidity/temperatures. The product data sheets for their bond breakers state:

“The number of coats and related application rate to achieve complete, uniform coverage of casting slab varies with concrete mix design, placing and finishing procedures, weather conditions, etc. Because of this, it is not possible to prescribe application rates or procedures inclusive of all site variables” (Nox-Crete, 2018).

This statement could be due to their past experiences involving tilt-up projects in adverse weather conditions. The responses from the participants who elaborated on the changes to their typical practice were generalized into two categories, one change states that they would apply thicker initial coat and/or more coats and the second change states that they would alter the time of application. The subcontractors had the highest rate of response with a total of nine (75%) subcontractors elaborating their changes, followed by two (16%) general contractors and one (9%) supplier. After reviewing the tallied results between each type of participant, the subcontractors had the largest discrepancy of responses. Seven of the nine subcontractors stated they would apply a thicker initial coat and/or more coats and the remaining two stated they would alter the time of application. This variation of responses could be due to past experiences between the subcontractors. However, since the manufacturer Nox-Crete does not provide any specific guidance for this subtopic, there is no conclusive answer between the two options provided from the responses.

Continuing the analysis of the Nox-Crete results, the following subtopic “Recent Precipitation” does offer guidance from the manufacturer’s product data sheets. Nox-Crete states, “Do not apply in rain or if rain is in the forecast within 12 hours of the application” and “Rain occurring prior to product drying will necessitate reapplication of bond breaker” (Nox-Crete, 2018). The responses from the participants who elaborated on the changes to their typical practice stated that they would backroll the product after the spray application. The subcontractors had the highest rate of response with a total of five (63%) subcontractors elaborating their changes, followed by two (25%) suppliers and one (12%) general contractor. After reviewing the tallied results between each type of participant, a majority of the participant’s responses involved a similar procedure to what the manufacturer’s recommendations stated. This accounted for 5 participants out of the total. Although two subcontractors and one supplier did state they would backroll the product after the spray application. This procedure of backrolling the product after the sprayed application is unique compared to any of the manufacturer’s recommendations. This procedure could be a unique adopted practice that varies between company experiences and a potential area for further research.

The last subtopic of interest from these results is regarding “Cold/Freezing Temperatures”, Nox-Crete’s recommendation for this weather consideration states, “Do not apply below 40°F (4°C) or when ambient temperatures are expected to fall below 40°F (4°C) within 12 hours of application” (Nox-Crete, 2018). The responses from the participants who elaborated on the changes to their typical practice were generalized into two categories, one change states that they would change the type of bond breaker and the second change states that they would apply lighter/least amount of coat as possible. The subcontractors had the highest

rate of response with a total of five subcontractors (56%) elaborating their changes, followed by three (33%) general contractors and one (11%) supplier. After reviewing the tallied results between each type of participant, the only participants who stated a procedure change similar to the manufacturer's recommendations were two subcontractors. However, three subcontractors, one general contractor, and one supplier did state that they would change the type of bond breaker being used in this situation. This change was discussed earlier in this chapter, noting that the chemical base of the bond breaker should be considered during freezing temperatures. A switch from water base to solvent base should be made due to the chemical properties of the product. For example, a water-based bond breaker could freeze during application and cause detrimental effects to the panel, while a solvent-based product would not have this issue (Dayton Superior, 2016). The response from this subtopic that was found to be the most interesting was the second change stating that they would apply a lighter or least amount of coat as possible. This procedure is very atypical compared to any bond breaker application procedure, it was noted that two general contractors indicated this change. This procedure should be further studied as to why cold or freezing temperatures would lead to applying less product. The results from Chapter 4 – Survey Results, Question 2.3 asking the participants to specify their region of tilt-up involvement it was noted that 18% of the participants are involved with tilt-up projects outside of the United States of America. Therefore, some of those participants could be involved with tilt-up projects in regions where cold/freezing temperatures are more prone to affect their site, for example in the regions of Canada. The compared results from these three subtopics and the recommendations from Nox-Crete further show the issues resulting from lack of knowledge related to the product installation that can be seen across all types of respondents.

Table 5 – Comparison of Results for Nox-Crete

Comparison of Results						
Nox-Crete						
Subtopic	Responses	GC	SUB	SUPP	ENGG	ED
High Humidity / Temperatures	0.) The number of coats and related application rate varies. Because of this, it is not possible to prescribe application changes.	-	-	-	-	-
	1.) Apply thicker initial coat and/or more coats.	1	7	-	-	-
	2.) Time of application	1	2	1	-	-
Recent Precipitation	0.) Rain occurring prior to product drying will necessitate reapplication. Do not apply if rain is in the forecast within 12 hours.	1	3	1	-	-
	1.) After spray application, backroll the product.	-	2	1	-	-
Cold / Freezing Temperatures	0.) Do not apply when ambient temperatures are expected to fall below 40°F (4°C) within 12 hours of application.	-	2	-	-	-
	1.) Change the type of bond breaker.	1	3	1	-	-
	2.) Apply lighter/least amount of coat as possible.	2	-	-	-	-

5.3.2 – Dayton Superior Results

The results from Table 6 below, show the results from the participants who specified that their typical bond breaker manufacturer as Dayton Superior, along with the respective recommendations from the manufacturer’s product data sheets. The results from the single subtopic “High Humidity/Temperatures” compared to the manufacturer’s recommendation show an inconsistency between each type of participants. As previously stated, the response rate for this manufacturer compared to Nox-Crete is significantly lower thus reducing the quantity of subtopics and responses to be discussed.

Unlike Nox-Crete, Dayton Superior did offer some recommendations over the subtopic regarding high humidity/temperatures. Their product data sheets for their bond breakers state for high humidity/temperatures, “casting slab must be flooded with water to reduce its porosity and cool it down prior to first application” (Dayton Superior, 2015a). The responses from the

participants who elaborated on the changes to their typical practice were generalized into two categories, similar to the response from the Nox-Crete participants. One change states that they would apply thicker initial coat and/or more coats and the second change states that they would alter the time of application. The type of participant with the highest response rate for this subtopic was the same as the Nox-Crete participants. The subcontractors had a total of seven (78%) participants, followed by two (22%) general contractors. As compared to the results from the Nox-Crete participants, the results from this analysis showed that the only two types of participants who elaborated on this subtopic were the subcontractors and general contractors, not including any supplier responses. After reviewing the tallied results between the two types of participants, the subcontractors had the highest inconsistency of changes to high humidity/temperatures. Surprisingly only one subcontractor stated a procedure change similar to the manufacturer’s recommendations. This was followed by the remaining six subcontractors and two general contractors divided equally between the other two changes. These results again show the wide difference of bond breaker application knowledge between these two types of participants.

Table 6 – Comparison of Results for Dayton Superior

Comparison of Results						
Dayton Superior						
Subtopic	Responses	GC	SUB	SUPP	ENGG	ED
High Humidity / Temperatures	0.) Thoroughly saturate the slab with water, squeegee off the excess, then immediately proceed with first application.	-	1	-	-	-
	1.) Apply thicker initial coat and/or multiple coats.	1	3	-	-	-
	2.) Time of application.	1	3	-	-	-

5.3.3 – Comparison of Results Summary

This section of the survey provided an assortment of insight and information from multiple types of participants covering the practice of concrete tilt-up design and construction with a focus on the bond breakers and their application process. Out of the entire data provided from this survey's section, this chapter focused its analysis on five questions from Section 3 and further studied their results. The analysis of these five questions of interest and their respective responses resulted in a thorough study of three manufacturer's product data sheets which then allowed for a comparison of the participants results to this study. It was noted through further analysis that neither the engineers nor the educators submitted a response for any of the subtopics. Additionally, due to lack of total responses only two of the three manufacturer recommendations were compared to the results. It was still conclusive through the results comparisons that discrepancies and knowledge barriers regarding bond breaker practices are present not only between participant types but potentially industry wide. This range of discrepancies over the application process of bond breakers could be due to the lack of acknowledgment and understanding of the bond breaker's respective product data sheets which could lead to detrimental effects on tilt-up projects.

Chapter 6 - Conclusion and Discussion

The concrete tilt-up industry is continuously growing and continues to be a common practice for reinforced concrete structures. Accompanying its growth is the use and application of bond breakers. In order to successfully and efficiently complete a tilt-up project, coordination between the field technicians is crucial. The results from the anonymous online survey that was given to industry professionals including suppliers, subcontractors, general contractors, and design professionals show that there are potential inconsistencies of practice and knowledge barriers regarding the application process of bond breakers. These results led to a study of the bond breakers' product data sheets for comparison to further verify these observations. This led to the question, how often are these product data sheets referenced in practice?

The anonymous online survey that was performed did not include questions of this aspect of the application process. Further research needs to be performed with the focus towards the field technicians and their knowledge of the application instructions provided in the technical data sheets. Requesting further information related to the typical process of providing installation instructions in the field would help identify where the gaps of product familiarity occur. The questions should focus on their practices before and during the application process, including during pre-installation meetings with the actual installers handling the products.

Furthermore, as stated in Chapter 2 – Literature Review it is recommended that TCA should bring similar awareness as they did for the glue-down process of architectural reveals after the OSHA 1926.1153 regulation towards the practice and process of bond breaker application. Providing further dedicated research and time towards development of a best practice guide for this aspect of the tilt-up process would be beneficial to the industry. A guide such as this will aid in minimizing issues and potential detrimental problems on tilt-up projects.

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Appendix A - Online Survey

Survey Questions		
No.	Question	Options
Section 1: Consent agreement		
1.1	Thank you for participating in this survey, the following question will state your consent to use the following answers as data for this research study of concrete tilt-up. The survey will cover the practices of concrete tilt-up design and construction with a focus on the preparation of the slab and formwork that the concrete panel it will interact with. The survey is voluntary and will take approximately 20 to 30 minutes, responses will be anonymous unless the participants chooses to provide their personal information at the end of the survey.	I agree / I do not agree
Section 2: Demographics/Background		
2.1	Which best describes your company or organization?	General Contractor / Subcontractor / Supplier / Engineer / Architect / Owner or Developer/Educator
2.2	Number of tilt-up projects your company or organization is involved with annually?	Sliding Scale: 0 - 20
2.3	Using the map provided, what region of the country does your company or organization primarily do tilt-up projects?	Northeast / Southeast / Midwest / Southwest / West / Outside of the U.S.



Survey Questions		
No.	Question	Options
2.4	What aspect of the tilt-up process is your company or organization primarily involved with?	Engineering / Architecture / Construction / Supplier or Manufacture
2.5	What area of the tilt-up process is your company or organization involved in?	Mix Design / Lifting Design / Bracing Design / Reinforced Design / Installation / Erection / Other: Please Specify
2.6	What typical buildings does your company or organization use tilt-up construction based on its occupancy type?	Industrial / Retail / Institutional / Office / Residential / Educational / Warehouse / Religious / Other: Please Specify
2.7	In your company or organization what is the typical height for tilt-up projects?	1 Story / 2 Story / 3 Story / +3 Story
2.8	In your company or organization what is the typical ground square footage for tilt-up projects?	0 - 20,000 SF / 20,001 - 50,000 SF / 50,001 - 100,000 SF / 100,001 - 200,000 SF / +200,000 SF
2.9	In your company or organization what percentage of projects use waste slabs compared to cast-in-place casting slabs?	Percentage Slide Scale: Waste Slab: 0 - 100% Cast in Place Slabs: 0 - 100%

Section 3: The use of bond breakers in tilt-up construction

3.1	What specific weather related issues affects your method of slab preparation before applying a bond breaker?	High Humidity / Recent Precipitation / High Winds / Other: Please Specify
3.2	What changes are taken into consideration in your typical practice when these climate issues are impacting the site? Select all that apply and explain the changes.	Method of Application / Coats of Application / Type of Bond Breaker / Other: Please Specify

Survey Questions		
No.	Question	Options

3.3	Identify which type of bond breaker are commonly used by your company or organization.	Solvent / Water-based / Oil-based / Silicone-free / Silicone water-based / Other: Please Specify
3.4	Specify which bond breaker product your company or organization commonly uses?	Please Specify
3.5	In your experience, is the type of bond breaker used on a project influenced by the architect?	Yes: Please Explain / No: Please Explain
3.6	What is your company or organization's preference between chemically and non-chemically active bond breakers?	Chemically Active: Please Explain / Non-Chemically Active: Please Explain
3.7	What is your company or organization's preferred method for finishing a cast slab?	Steel Trowel / Laser Screed Placement / Dependent on the Contractor / Dependent on the Specifications / Other: Please Specify
3.8	What is the typical slab curing time prior to the application of the bond breaker?	12 Hours / 24 Hours / 36 Hours / 48 Hours / 60 Hours / 72 Hours / 4 Days / 5 Days / 6 Days / 7 Days / 14 Days / 28 Days / Other: Please Specify
3.9	Does your company or organization follow ASTM D4263, the testing method to indicate the presence of capillary moisture in concrete?	Yes / No
3.10	What is the typical moisture content that is required for a cast-in-place casting slab?	Percentage Slide Scale: Typical Moisture Content: 0 - 100%
3.11	What is the typical procedure for cleaning the casting slab prior to placement of concrete?	Please Specify
3.12	Does the ambient temperature have an effect on the application of bond breaker?	Yes / No

Survey Questions

No.	Question	Options
3.13		

	Based on the previous question, what considerations are taken? Please explain your answer.	Method of Application / Coats of Application / Time of Application / Other: Please Specify
3.14	Does the ambient air temperature have an effect on how your company or organization stores bond breakers?	Yes / No
3.15	Based on the previous question, what considerations are taken? Please explain your answer.	Please Specify
3.16	How does weather affect your typical process for applying release agents?	Please Specify
3.17	What is your company or organization's preferred method for removing bond breaker residue?	Residue is not removed / Power washing / Other: Please Specify
3.18	What typical process does your company or organization use to remove any chemicals or residue from the casting slab prior to applying the bond breaker?	Please Specify
3.19	What impacts do vehicular traffic (cranes, equipment, etc.) have on the bond breaker application process?	Please Specify
3.20	Does the use of concrete hardeners in the casting slab impact your selection of bond breaker? Please explain your answer.	Yes / No
3.21	Does the use of colored concrete in the casting slab impact your selection of bond breaker? Please explain your answer.	Yes / No
3.22	Does the use of fiber reinforcement in the casting slab impact your selection of bond breaker? Please explain your answer.	Yes / No

Survey Questions

No.	Question	Options
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Section 4: Closing Statement

4.1	Thank you for participating in this survey over concrete tilt-up. The results of the survey will be analyzed and used for a Master's Report by Eduardo Moran (Kansas State University, Architectural	Name: Email:
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Engineering graduate student) and will be available for the public in the Spring of 2018. If you would like to participate in more follow up questions regarding the subject, please leave your information below (not required).

Appendix B - Chapter 5 Results

Comparison of Results						
Nox-Crete						
Subtopic	Responses	GC	SUB	SUPP	ENGG	ED
High Humidity / Temperatures	0.) The number of coats and related application rate varies. Because of this, it is not possible to prescribe application changes.	-	-	-	-	-
	1.) Apply thicker initial coat and/or more coats.	1	7	-	-	-
	2.) Time of application	1	2	1	-	-
Recent Precipitation	0.) Rain occurring prior to product drying will necessitate reapplication. Do not apply if rain is in the forecast within 12 hours.	1	3	1	-	-
	1.) After spray application, backroll the product.	-	2	1	-	-
Cold / Freezing Temperatures	0.) Do not apply when ambient temperatures are expected to fall below 40°F (4°C) within 12 hours of application.	-	2	-	-	-
	1.) Change the type of bond breaker.	1	3	1	-	-
	2.) Apply lighter/least amount of coat as possible.	2	-	-	-	-
High Winds	0.) N/A	-	-	-	-	-
	1.) Apply additional coats.	-	1	-	-	-
Dayton Superior						
Subtopic	Responses	GC	SUB	SUPP	ENGG	ED
High Humidity / Temperatures	0.) Thoroughly saturate the slab with water, squeegee off the excess, then immediately proceed with first application.	-	1	-	-	-
	1.) Apply thicker initial coat and/or multiple coats.	1	3	-	-	-
	2.) Time of application.	1	3	-	-	-
Recent Precipitation	0.) Rain occurring prior to product drying will necessitate reapplication. Do not apply if rain is in the forecast within 12 hours.	1	2	-	-	-
	1.) Change type of bond breaker.	1	-	-	-	-
Cold / Freezing Temperatures	0.) Do not apply when ambient temperatures are expected to fall below 40°F (4°C) within 12 hours of application.	-	1	-	-	-

Comparison of Results

SpecChem

Subtopic	Responses	GC	SUB	SUPP	ENGG	ED
High Humidity / Temperatures	0.) Before application, saturate the slab surface with water. Apply successive coats until surface appears uniformly dark.	-	-	-	-	-
	1.) Apply thicker initial coat and/or multiple coats.	1	1	-	-	-
	2.) Time of application.	1	-	1	-	-
Recent Precipitation	0.) Rain occurring prior to product drying will necessitate reapplication. Do not apply if rain is in the forecast within 12 hours.	1	-	-	-	-
	1.) Reapply the product.	-	1	-	-	-
Cold / Freezing Temperatures	0.) Do not apply when ambient temperatures are expected to fall below 40°F (4°C) within 12 hours of application.	-	-	-	-	-
	1.) Change type of bond breaker.	1	1	1	-	-