



Analysis of COVID-19 Concerns Raised by the Construction Workforce and Development of Mitigation Practices

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The coronavirus outbreak has created a global health crisis that has disrupted all industries, including the construction industry. Following the onset of the pandemic, construction workers faced and continue to face unprecedented safety and health challenges. Therefore, construction employers established new safety precautions to protect the health and safety of the workforce and minimize the spread of the virus. The new precautions followed the advice and guidelines offered by different health and safety agencies like the Occupational Safety and Health Administration (OSHA), Centers of Disease Control and Prevention (CDC), and the Associated General Contractors of America (AGC). With construction projects resuming operations, it becomes important to analyze the coronavirus-related health and safety concerns of construction workforce and understand how the new safety procedures can assist on jobsites. Existing studies mostly focused on interviews and surveys with construction companies to understand the impact on project performance and supply chains. However, no study has yet to analyze the United States construction workforce. This paper fills the gap by providing a qualitative descriptive analysis of the COVID-19 complaints data gathered by OSHA from construction jobsites. Information gathered by OSHA includes the jobsite location, the North American Industry Classification System (NAICS) of the construction company, the type of the complaint (i.e., formal or non-formal), and a thorough description of the complaint. N-grams were employed to analyze the complaints, detect trends, and compile a list of the most frequent concerns reported by the workforce. The analysis of the complaints data identifies safety practices that were most violated, highlights major safety and health concerns for construction workers, and pinpoints geographical areas that have seen a surge in complaints. The study also synthesized the existing research corpus and compiled a list of 100 best practices that construction employers can adopt to mitigate the concerns of the workforce. The findings of this study provide insights into the safety and health trends on construction sites, lay the foundation for future work of academicians and practitioners to address the concerns faced by construction workers, and serve as lessons learned for the industry in the case of any future pandemic.

Keywords: COVID-19 pandemic, construction industry, complaints, health, recommendations, safety, workers

INTRODUCTION

Coronavirus disease (COVID-19) is a recently discovered disease caused by the novel coronavirus SARS-CoV-2 (World Health Organization, 2021). First detected in December 2019 in Wuhan, China, COVID-19 rapidly spread around the world becoming a global pandemic in March 2020 (World Health Organization, 2020). The virus spreads mostly through droplets released from coughs and exhales, where the droplets may disperse on surrounding surfaces and infect people at a close proximity (Wang L. et al., 2020). The virus can cause severe illnesses to high-risk groups such as those with underlying medical conditions like high blood pressure, heart and lung problems, diabetes, obesity or cancer (Wang D. et al., 2020; World Health Organization, 2020). Nonetheless, any person from any age or medical condition can contract COVID-19 and develop serious illnesses, even death (World Health Organization, 2020). As of March 2021, more than 120 million people around the globe have tested positive for COVID-19 resulting in a death toll that surpassed 2.7 million people (Hopkins, 2021).

To slow the spread of the virus, governments had to implement preventive measures to rapidly respond to the virus such as creating provisions for medical services, designating hospitals for COVID-19, developing isolation areas and testing facilities, and issuing public relief packages and financial assistance (Nawaz et al., 2020a). Governments also had to place restrictions on travels, enforced lockdowns, and limited mobility to essential works (Nawaz et al., 2020a; Jamaludin et al., 2020). The outbreak of the virus and the measures to contain it created worldwide halts to major industries, causing global stock markets to suffer dramatic falls and the global economy to shrink 4.4% in 2020—the worst since the Great Depression of the 1930s (Jones et al., 2021; Szmigiera, 2021). The construction industry is no exception. Known for being sensitive to economic cycles, the construction industry was particularly vulnerable to the drastic decline in economic activity caused by the pandemic (International Labour Organization, 2021).

Prior to the COVID-19 pandemic, there was a pressing need in the construction industry to increase productivity, improve project performance, address labor shortage, reduce fragmentation, introduce standardization, and increase collaboration (Oesterreich and Teuteberg, 2016; Barbosa et al., 2017; Nassereddine et al., 2020a, 2020b; El Jazzer et al., 2020a, 2020b; Bou Hatoum et al., 2020; Hatoum and Nassereddine, 2020; Sawhney et al., 2020). In addition to that, the labor-intensive nature of construction projects and the dynamic nature of construction sites make the construction industry one of most hazardous industries in the world (OSHA, 2019; OSHA, 2020a; Eurostat, 2020; Hatoum et al., 2020). Factors such as unsafe work practices, limited information, risky working condition, lack of technical and material support, negligence in adopting safety rules and laws, and lack of communication worsened the safety and health status on construction sites (Nawaz et al., 2020b). When the pandemic hit, the status of construction projects worsened: more projects suffered from cost and time overruns, material supply chains were disturbed, unemployment increased, the availability of workers decreased, and health and safety

became an even bigger concern (International Labour Organization, 2021). Thus, major agencies such as the Center for Disease Control and Prevention (CDC), the Occupational Safety and Health Administration (OSHA), and the Associated General Contractors of America (AGC) released a set of guidelines that construction employers can follow to safely resume work on construction projects as they weather the pandemic storm (OSHA, 2020b; CDC, 2020; AGC, 2021). Moreover, several studies from various parts of the world were published to report on both the status of construction projects and the safety and health precautions that construction companies are implementing on construction projects (Shibani et al., 2020; Alsharaf et al., 2021; Ebekozi and Aigbavboa, 2021; Simpeh and Amoah, 2021).

With the topic of health and safety management being at the forefront of the concerns of the construction industry during the COVID-19 pandemic, most of the published studies have focused on analyzing the impact of the pandemic on project performance and developing guidelines to safely execute projects by collecting data through interviews or surveys with selected subject matter experts (Jamaludin et al., 2020; Majumder and Biswas, 2021; Simpeh and Amoah, 2021). While construction workers are the heartbeat of every construction project, there has been limited discussion on the perception of workers in the pandemic and the effectiveness of the newly established safety measures. One tool that has been available to workers in the United States of America (USA) to report on their safety concerns is the OSHA Complaint tracker. OSHA is a large regulatory agency of the United States Department of Labor with a main mission to inspect and examine the health and safety in workplaces in various industries, including the construction industry (OSHA, 2020c). Construction workers had access to the OSHA Complaint tracker during the pandemic, and complaints made by construction workers nationwide were compiled into a database that is published on the OSHA website. The investigation of this database can provide great insights into the perception of the construction workers of how well the construction projects were managed during the pandemic. Therefore, this paper provides a qualitative descriptive analysis of the COVID-19 construction-related complaints published by OSHA to better understand the nature of concerns of the USA workforce. Moreover, using the existing research corpus and the guidelines released by official agencies, the study outlines a list of 100 recommendations to tackle the concerns highlighted by the workers to enable the construction industry to safely navigate through the pandemic.

LITERATURE REVIEW

Numerous studies were performed to investigate the impact of the pandemic on the construction industry. Hansen (2020) described COVID-19 in the context of the construction industry as an unforeseeable, unavoidable, uncontrollable, and impractical event that is beyond the reasonability of any party. According to the author, the event was unforeseeable as it started from Wuhan and spread across the globe at an unprecedented

scale, unavoidable because all industries were affected including the labor-intensive construction industry, uncontrollable since its impact is beyond the control of contracting parties, impracticable because its direct and indirect impacts on the construction industry affects the fulfillment of contractual obligations, and beyond the responsibility of any party given that it is a global health crisis and declared by many countries as a national disaster (Hansen, 2020). The author suggested that the contractor and employer should establish a COVID-19 prevention task force capable to educate workers on the virus, coordinate with the hospitals, identify potential risks and virus spreads, and control the health and safety on the construction site (Hansen, 2020).

Impacts of the COVID-19 Pandemic on the Construction Industry Worldwide

Gamil and Alhagar (2020) collected input from a survey conducted on 129 respondents and a series of structured interviews with 10 experts to understand the impact of COVID-19 on construction. According to respondents, the most severe impacts of the pandemic are: (1) suspension of projects due to constraint movements and supply shortage, (2) workforce shortage due to suspension of projects and the spreading of the virus in gatherings, (3) time overrun which is associated with the movement and measure control period, and (4) cost overrun and financial impact caused by the economic deterioration, project suspension, and ongoing overhead costs to keep companies running (Gamil and Alhagar, 2020). Other impacts include supply shortage, material price fluctuations, legal issues and interruptions in contractual terms, impact on existing accomplished activities, uncertainty of survival, and impact on research and technology (Gamil and Alhagar, 2020). Moreover, Ogunnusi et al. (2020) identified common positive and negative experiences with COVID-19 through a questionnaire conducted with 71 construction industry professionals from different regions around the world (54.9% of respondents from Africa, 2.5% from Asia, 18.3% from Europe). When asked about positive impacts, respondents agreed that “the opportunity to improve on virtual alternatives” has been empowered by the pandemic where digital platforms have enabled the continuity of meetings previously held as face-to-face only (Ogunnusi et al., 2020). Other positive impacts include deploying and enhancing the use of technology, improving material planning and workplace design, encouraging collaboration and risk assessment, emphasizing on Personal Protective Equipment (PPE), and increasing off-site works (Ogunnusi et al., 2020). As for negative impacts experienced by the respondents, the pandemic has worsened ongoing project problems such as cost and schedule overruns, mainly due to the daily hardships faced by labor and the ineffective work from home for site-based processes (Ogunnusi et al., 2020).

Impact of the COVID-19 Pandemic on Regional Construction Industries

While researchers have been mostly discussing the impact of the pandemic on the construction industry worldwide, some studies

were more specific to certain regions. Examples of these studies are shown in **Table 1**.

Impact of the COVID-19 Pandemic on the United States Construction Industry

In the USA, Alsharef et al. (2021) conducted a series of structured interviews with 34 construction professionals on the impacts of the pandemic on their work. General and adverse impacts of the pandemic included: (1) disparities across states on whether construction operations are essential or non-essential, (2) material delivery delays and shortage of material, (3) increase in demands from local suppliers and manufacturers, (4) delays in inspections and securing permits, (5) reduction in efficiency and production rate, (6) suspension or slowing of ongoing projects and delay in the start of new projects, (7) price escalations, additional costs, loss of revenue, payment delays, (8) safety concerns regarding virus spread in workplaces, (9) transition to work from home for non-site personnel, and (10) expected increase in disputes, litigation, and claims (Alsharef et al., 2021). Moreover, the authors brought awareness to the efforts needed to mitigate the challenges through developing new safety measures to keep construction sites safe, and managing various project risks such as time delays, costs overruns, and material shortage. The study also discussed new opportunities that may arise due to the pandemic, including the ability to secure loans at low-interest rates, recruitment of skilled workers post-pandemic, and increase in demand for certain types of projects such as transportation, infrastructure, warehouses, residential, fast-track medical, and public facilities (Alsharef et al., 2021). Other major opportunities include the internal reviews that companies will undergo to improve existing systems such as rethinking current processes, utilizing technology, reducing operational and overhead costs, and enhancing equipment and tools (Alsharef et al., 2021).

Studies Related to the Health and Safety Concerns of the Construction Workforce

In addition to the above studies, some researchers tackled the safety and health concerns of the construction workforce. (Pamidimukkala et al., 2021) highlighted major safety and health concerns that the construction workforce may face in the COVID-19 pandemic. According to the study, concerns include (1) concerns about the risk of being exposed to the virus at work, (2) thinking of personal and family while working, (3) managing different workloads, (4) isolation, (5) lack of access to tools and equipment needed to perform the job, (6) feeling of not contributing enough for work, (7) uncertainty about the future of the workforce, (8) adapting to different workplaces and new schedules, and (9) learning new communication tools and dealing with technical difficulties. The study suggested that implementing some measures can mitigate the effect of the concerns. Such measures include redefining jobsite safety, increasing technology use, prolonging project timelines, increasing remote work, adding flexibility to work schedules, providing extra training, enhancing communication, and teaching to recognize stress symptoms (Pamidimukkala et al.,

TABLE 1 | Selected studies on the impact of the COVID-19 pandemic on regional construction industries.

Country	Means	Insights
India	Literature review and industry press releases	<ul style="list-style-type: none"> • Pandemic had negatively impacted the labor market, supply of materials, supply of equipment, company liquidity, project delivery, supply chain disruptions, funding restrictions, and cash-flow concerns Majumder and Biswas (2021) • Lockdowns led to unanticipated project delays, governmental orders and permit delays, and reduce crew size with social distancing Majumder and Biswas (2021)
Kuwait	Surveys	<ul style="list-style-type: none"> • Delays in construction projects were deemed by industry practitioners as critical delays. Government enforced site shutdowns during the day and night, delaying project completions Alenezi (2020)
Malaysia	Interviews	<ul style="list-style-type: none"> • For housing projects: While government enforcements enhanced the safety on construction projects and limited the spread of COVID-19, the order affected project progressions in terms of time delays, cost overruns, declined workforce and excessive layoffs, and limited resource availability Esa et al. (2020) • For infrastructure projects: The increase in uncertainties in mega projects led to different consequences varying between financial matters such as lack of overhead costs to keep companies running due to delayed payments, and productivity matters due to lack of materials and labor shortage King et al. (2021) • Other disruptions included delays in project timelines due to late authority approvals, reduced labor since foreign workers had to leave while no new workers were able to enter the country, and material delays due to cross-country procedures and suppliers running short of supplies Zamani et al. (2021)
Nigeria	Interviews	<ul style="list-style-type: none"> • Lockdowns caused transportation problems for materials and labor, reduced daily working hours, and project abandonment Osuizugbo (2021) • Other major disruptions included delay in construction activities leading to cost overruns, inflated costs of construction materials, lack of funding affecting money release from clients, and shortage of labor Osuizugbo (2021)

2021). Zheng et al. (2021) investigated the knowledge, attitudes, and practices (KAP) of construction industry practitioners in China. Results revealed that a significant minority of practitioners did not have enough information about the spread of the virus, a significant majority was optimistic about winning the battle against COVID-19, and more safety measures should be enforced (Zheng et al., 2021). In another study, Denny-Smith et al. (2021) provided recommendations on how construction employers can create social value and assist recovery from the COVID-19 crises. The study recommends that future construction investments that create new jobs and/or reopen lost ones after the COVID-19 lockdowns should provide both culture and work benefits. For example, besides adequate pays and incomes, companies should be more inclusive and diverse, engage more with their communities, embrace cultures, and provide employees with a better work-life balance, good mental health management practices, more opportunities to grow, and enhanced guidance and communication from management. Such benefits can create much-needed social value to employees who are rebuilding their life after the COVID-19 pandemic (Denny-Smith et al., 2021).

METHODOLOGY

The main objective of this paper is to investigate the perceptions of construction workers in USA on how well health and safety measures were imposed on construction projects during the pandemic. This overarching objective is achieved through two intermediate objectives: (1) analyze the construction-related complaints submitted to the OSHA Complaint tracker, and (2) outline a list of recommendations to tackle the concerns.

To achieve the first intermediate objective, the COVID-19 complaints database was first downloaded from the OSHA

website. The data was sorted by the North American Industry Classification System (NAICS) index to only extract the construction-related complaints. As a result, the database for closed COVID-19 safety and health compliance data included a total 1,403 complaints associated with the construction industry (around 3.3% of the total dataset). All the complaints were recorded between March 1st, 2020 and January 18th, 2021. Each complaint included information on the company for which the worker works, such as company name, address, and the North American Industry Classification System (NAICS) index. Additional information included the means by which the complaint was received, the type of the complaint, and a description of the hazards for each complaint. The names and addresses of the companies were excluded from the study and only the state where the complaint was filed is reported. Then, the text mining technique N-gram was employed to analyze the complaints, detect trends, and compile a list of the concerns that were most frequently reported by the workforce.

To achieve the second intermediate objective, the authors reviewed numerous studies that surveyed or interviewed construction employers and examined the latest guidelines released by OSHA, CDC, and AGC to compile a set of recommendations to address the concerns identified in the first objective. A list of 100 best practices that were grouped by common themes was identified.

ANALYSIS OF COMPLAINTS

The OSHA online database for closed COVID-19 safety and health compliance data included a total 1,382 complaints associated with the construction industry and recorded between March 1st, 2020 and January 18th, 2021. The names and addresses of the companies were excluded from the study and

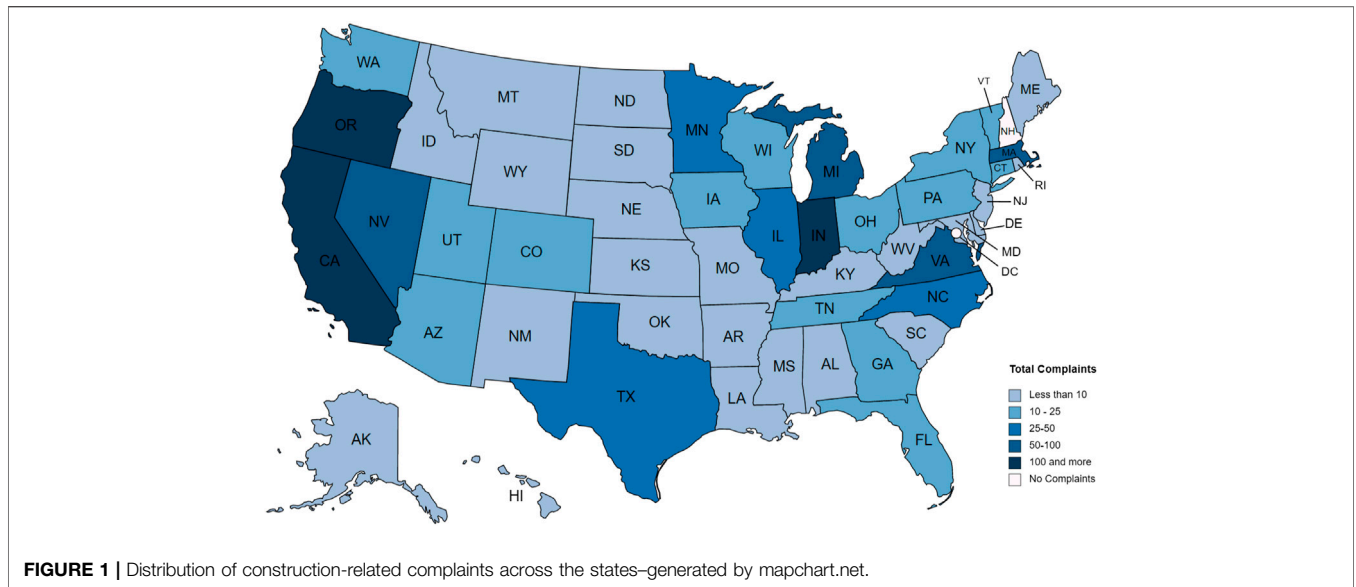


FIGURE 1 | Distribution of construction-related complaints across the states—generated by mapchart.net.

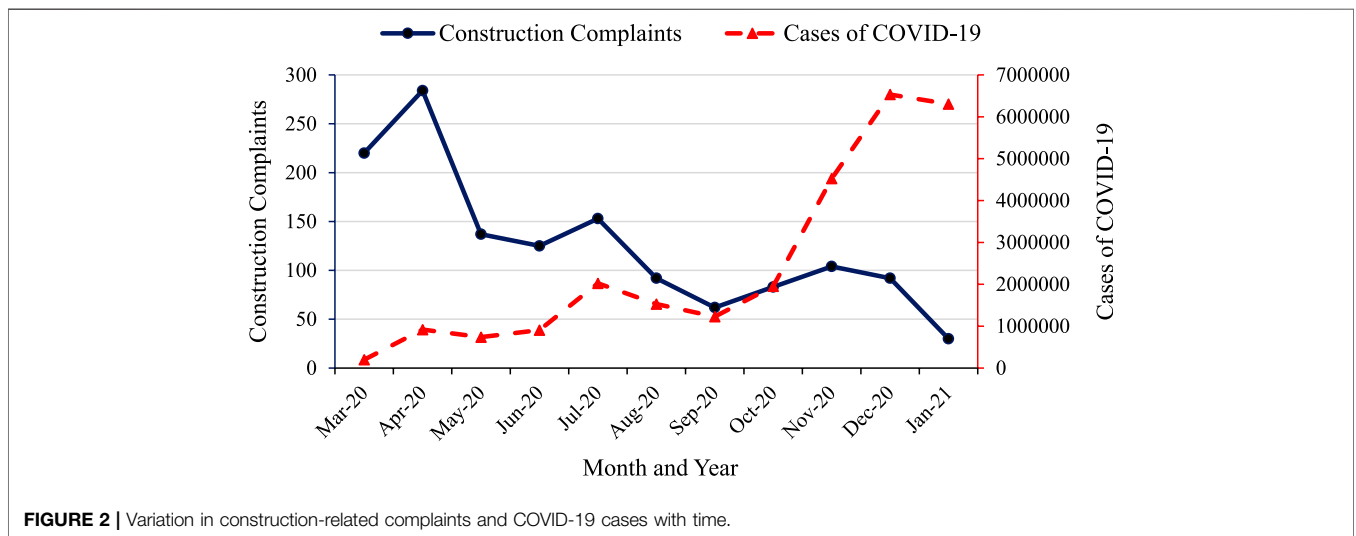


FIGURE 2 | Variation in construction-related complaints and COVID-19 cases with time.

only the state in which the complaint was filed was reported to enable geographical analysis. The following sections describe the various features and variables included in the OSHA database. Analysis was performed using RStudio, and graphs were generated using RStudio and Microsoft Excel (Microsoft Corporation, 2021; RStudio Team, 2021).

Distribution of Complaints by State

To gain insights into what states were experiencing more health and safety violations, the 1,382 complaints were mapped according to the geographic location as illustrated in **Figure 1**. The map shows that most complaints were filed in California (18.7%), followed by Oregon (17.2%), Indiana (8.8%), Nevada (7.1%), then Michigan (5.4%). New Hampshire was the only state with no construction-related complaints, and so was Washington D.C.

Distribution of Complaints by Time

The total number of construction-related complaints recorded each month for the period between March 2020 and mid-January 2021 is plotted in **Figure 2**. According to the results, the highest number of construction-related complaints closed by OSHA in 2020 was in April (284), and the lowest was in September (62). As far as 2021, the number of complaints recorded as of January 18th, 2021 was (30), less than half of what was recorded in September 2020.

When comparing the trend of construction-related complaints to the trend of COVID-19 cases in the USA, it can be noted that the construction-related complaints were higher in the early stages of the pandemic. However, complaints from the construction workforce gradually decreased despite the continuous increase in confirmed positive COVID-19 cases. This increase in construction-related complaints amid the

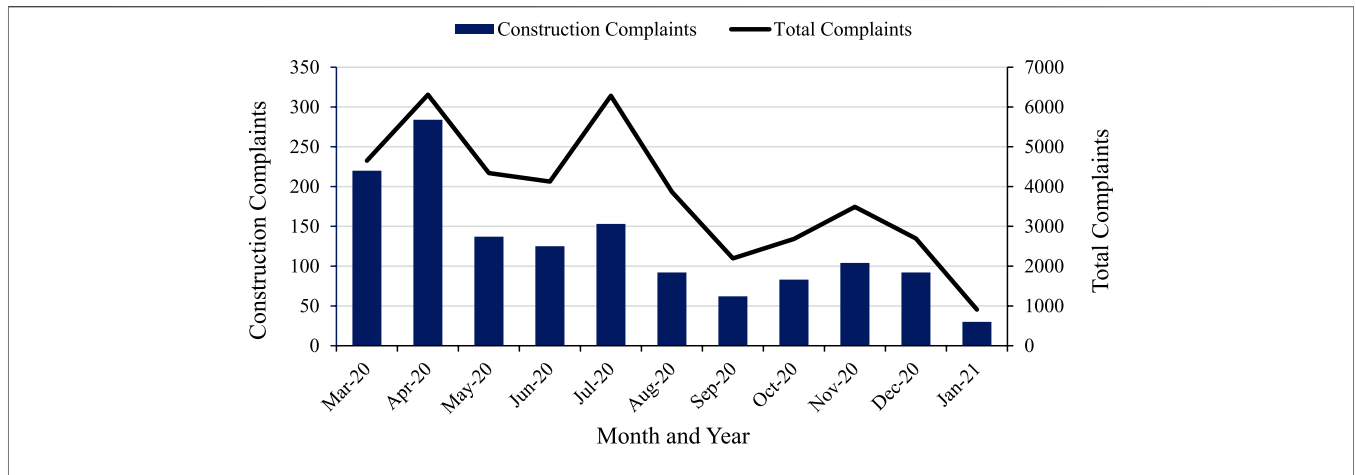


FIGURE 3 | Variation of construction-related complaints as compared to the total complaints with time.

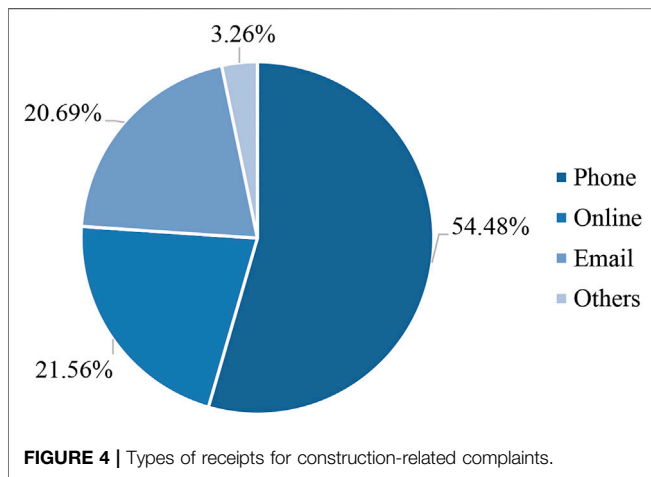


FIGURE 4 | Types of receipts for construction-related complaints.

Distribution of Complaints by Receipt

Regarding the types of receipts used by workers to communicate construction-related complaints, more than half of the employees used the phone (54.5%) as seen in **Figure 4**, 21.56% submitted their complaints online, and 20.69% via email. The other receipts included complaints filed using a hotline (1.5%), mailed (1.1%), faxed (0.5%), and submitted in-person (0.2%). The only type of receipts that was not used for reporting construction-related complaints was the media.

Distribution of Complaints by NAICS

Based on the NAICS distribution of the data, 45% of the complaints were related to the *Construction of Buildings*, 44% to *Specialty Trade Contractors*, and 11% to *Heavy and Civil Engineering Construction*. The distribution of the complaints for each category is shown in **Figure 5**.

For the *Construction of Buildings* category, residential construction complaints varied between new single-family housing construction (39%), new multifamily housing construction (23.4%), new housing for-sale builders (6.9%), and residential remodelers (3.7%). On the other hand, non-residential construction complaints varied between industrial (13.9%) and commercial and institutional (86.1%) building construction.

For the *Heavy and Civil Engineering Construction* category, complaints in the utility system construction varied between the construction of water and sewer line and related structures (42.4%), power and communication lines and related structures (42.4%), and oil and gas pipeline and related structures (15.2%).

For the *Specialty Trade Contractors* category, the distribution of the sub-categories (and the sub-sub-categories) is displayed in **Figure 6**. Overall, the specialty trade contractors that had the most complaints were electrical contractors and other wiring installations (9.6% of total construction-related complaints), followed by plumbing, heating, air conditioning contractors (8% of total construction-related complaints), roofing contractors (2.8% of total construction-related complaints),

active spread of COVID-19 can be attributed to the scarcity of information about the virus in USA and the little guidance provided from safety and health agencies. As a result, construction companies needed time to understand the spread of the virus and its impacts on their operations in order to develop a plan to mitigate these impacts. After enforcing major lockdowns across the USA in Spring of 2020 and as more health and safety guidelines were being published, construction-complaints started to gradually decrease, indicating that the construction industry was becoming better at controlling the spread of the disease and adopting the appropriate safety measures.

It should also be noted that the change in the number of construction-related complaints was directly proportional to the total number of closed complaints recorded from all industries every month (**Figure 3**), where construction-related complaints collected between March 2020 and January 2021 averaged 3.3% of all COVID-19 complaints. The highest percentage of construction-related complaints were recorded in March and April where construction tallied 4.7 and 4.5% of all complaints. The lowest percentage of construction-related complaints was observed in July and August with 2.4 and 2.3% respectively.

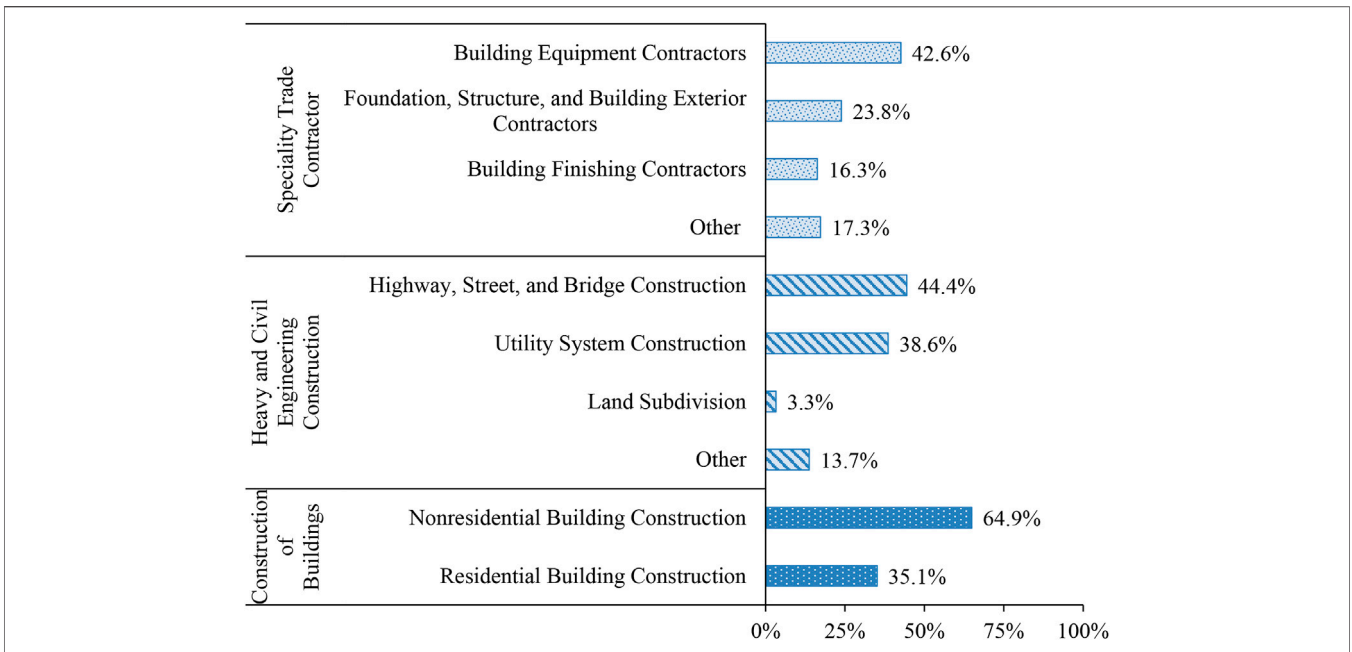
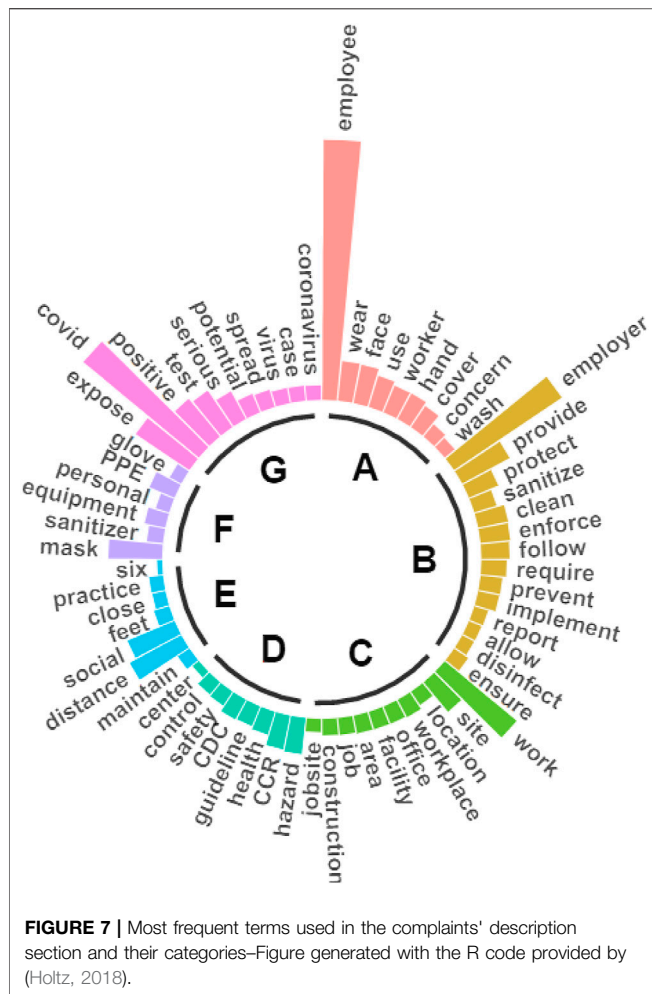


FIGURE 5 | Distribution of the construction-related complaints across the NAICS subcategories.



FIGURE 6 | Distribution of "specialty trade contractor" complaints.



and site preparation contractors (2.2% of total construction-related complaints).

Formality of Complaints

An important factor to consider when analyzing construction-related complaints is the type of the complaint. According to OSHA, complaints can be either formal or non-formal. A formal complaint is defined by OSHA as a “complaint made by a current employee or a representative of employees that meets three requirements: (1) asserts that an imminent danger, a violation of the Act, or violation of an OSHA standards exposing employees to physical harm exists in the workplace; (2) reduced to writing or submitted on an OSHA-7 form; and (3) signed by at least one current employee or employee representative” (OSHA, 2020c). A non-formal complainant is “any complaint alleging safety or health violations that does not meet all of the requirements of a formal complaint identified above” (OSHA, 2020c). According to the data, 26% of the construction-related complaints were formal and the remaining 74% were non-formal. When compared to the entire dataset of all COVID-19 complaints, construction-related complaints accounted for 2.8% of all formal complaints, and 3.6% of all non-formal complaints.

Reasons for Complaints

For each complaint reported by construction workers, a description was provided to elaborate on the concerns. To gain insights into the major concerns of construction workers, the descriptions were analyzed to identify the most frequently used words that could highlight health and safety concerns for the construction workforce. **Figure 7** summarizes the most frequent terms identified in the construction-related complaints submitted by the construction workers. The figure was generated using RStudio (RStudio Team, 2021). Prior to creating this figure, the raw description of the 1,382 complains was pre-processed and cleaned by removing punctuation, changing words to lowercase letters, deleting numbers, and removing extra white spaces. Then, since the data was captured in English, English stop words, i.e., words that can be removed without affecting the meaning of the sentence, were removed from the descriptions. For instance: “and”, “but”, “the”, “because”, “he”, “she”, and the likes were all deleted from the raw descriptions. The data was also stemmed to reduce words to their base or root forms, and then counted. Stemmed words that were used at least 100 times were reviewed, and then grouped in terms of similarities and associations.

Applying frequency analysis to the cleaned dataset resulted in seven categories as illustrated in **Figure 7** and discussed in **Table 2**: terms related to employees (Category A), terms related to employers (Category B), terms related to place of work (Category C), terms related to health and safety agencies (Category D), terms related to social distancing (Category E), terms related to safety wearables and carry-ons (Category F), and the terms related to the COVID-19 virus (Category G).

During this process, stemmed words were also reviewed in their original form to make sure of their intended use. For example, “employees” and “employers” shared common stems, so the frequency of their original forms was considered. Another example is “sanitized” and “sanitizer”; while “sanitizers” had associations with hand and soap, “sanitized” was associated with materials, objects, and rooms on construction sites.

To extract valuable insights from the provided descriptions, the N-gram text mining technique was employed to analyze the concerns submitted by the construction workforce and find common themes. N-gram can be simply defined as a sequence of “N” words (Jurafsky and Martin, 2020). For example, breaking “employer did not enforce masks” into 2-g will result in “employer did”, “did not”, “not enforce”, and “enforce masks”. Breaking the same sentence into 3-g will result in “employer did not”, “did not enforce”, “not enforce masks”. 2-g are normally referred to as bigrams, while 3-g are referred to as trigrams (Kumar, 2017).

In this study, the code was run to compile frequent bigrams, trigrams, 4-g, 5-g, 6-g, 7-g, 8-g, and 9-g. After examining and analyzing the generated lists, the following nine concerns were derived:

- Personnel who tested positive continued to report to work
- Personnel who were exposed to the virus continued to report to work
- Employers did not enforce social distancing

TABLE 2 | Description of categories.

Category	Description	Insights
A	Terms related to employees	The most frequent word in the category is “employee” (2033 occurrences), and the lowest is “wash” (100 occurrences). Worker, a synonym to employee, also occurred 224 times. The terms refer to concerns on washing face, washing hands, and using face wear
B	Terms related to employers	The most frequent word in the category is “employer” (1015 occurrences), and the lowest is “ensure” (100 occurrences). All of the terms in this category are action verbs that employers should take to stop the virus spreading, such as “provide”, “protect”, “sanitize”, “enforce”, “require”, and “prevent”.
C	Terms related to workplace	The most frequent word in the category is “work” (730 occurrences), and the lowest is “jobsite” (102 occurrences). All of the terms in this category act as synonyms to the workplace as depicted by the construction industry, such as “site”, “location”, “area”, and “office”.
D	Terms related to health and safety agencies	The most frequent word in the category is “hazard” (281 occurrences), and the lowest is “control” (121 occurrences). The terms in this category refer to the health and safety guidelines set by agencies such as CDC (center for disease and control) and CCR (California code of regulations). The term “center” (60 occurrences) was also added due to its association with the terms: “Center” and “disease”.
E	Terms related to social distancing	The most frequent word in the category is “maintain” (107 occurrences), and the lowest is “practice” (105 occurrences). The terms in this category refer to practicing social distancing and keeping a minimum of 6 ft (1.83 m) distance. The term “six” appeared 36 times however the number 6 occurred 156 times (numbers were removed during the cleaning process). Thus, the total occurrences of “six” and “6” exceed a 100 times and term “six” was also added to the figure
F	Terms related to safety wearables and carry-ons	The most frequent word in the category is “mask” (481 occurrences), and the lowest is “glove” (100 occurrences). The terms in this category refer to safety wearables like “PPE” and “mask”, and carry-ons like “sanitizer”.
G	Terms related to the COVID-19 virus	The most frequent word in the category is “expose” (504 occurrences), and the lowest is “coronavirus” (113 occurrences). The terms in this category refer to virus and positive cases, terms include “positive”, “potential”, “test”, and “case”.

- Employers did not provide masks and PPE such as gloves and face shields
- Employers did not provide hand-wash facilities and hand-wash sanitizers
- Employers did not take precautions to protect employees from contracting the virus as set by the safety and health agencies, or state local policies
- Employers did not disinfect or deep clean the workplace
- Employees were not wearing face covers despite the mask mandates

BEST PRACTICES AND RECOMMENDATIONS

The above section highlighted the health and safety concerns that construction labor developed during the COVID-19 pandemic. To mitigate these concerns, construction companies implemented a set of guidelines as recommended by health and safety agencies such as OSHA, CDC, and AGC. Other companies went beyond the guidelines and established their own stringent regulations to better control the spread of the virus and protect their employees. These guidelines, if followed, can be extremely important to resolve the health and safety concerns raised by the construction workforce through their complaints to OSHA. As new information about the virus and its spread comes to light, OSHA, CDC, and AGC are continuously updating their guidelines. While all published guidelines aim to provide a healthy and safe workplace for construction workers, the practices identified by the three health and safe agencies are complementary. Therefore, this section summarizes the different best practices of OSHA

TABLE 3 | Recommended practices to control access points.

Code	Practice
P1	Install disinfecting tunnels on entrances and exits (if possible)
P2	Install temperature guns or scanners on entrances
P3	Maintain daily site registers for employers and visitors
P4	Provide identity cards for everyday employees (if possible)
P5	Quantify restrictions of transportation vehicles
P6	Screen employees regularly for possible virus exposure

(OSHA, 2021), CDC (CDC, 2021), and AGC (AGC, 2020) and recommendations outlined by Han et al. (2020), Jamaludin et al. (2020), Lovcheva (2020), Mitchell (2020), Assaad and El-adaway (2021), Majumder and Biswas (2021), and Simpeh and Amoah (2021). The best practices are clustered into 11 themes: access points, communication and awareness, compliance, daily tasks and activities, engineering controls, exposure response plan, human interactions, hygiene and sanitization, management of deliveries, physical and mental health, and safety wearables and carry-ons. It is important to note that all the best practices mentioned were comprehensively compiled from the listed references. Moreover, the 11 themes and their corresponding practices are not listed in an ascending or descending order, but rather they are listed in alphabetical order.

Access Points

The objective of this theme is to control access points to the workplace, which can be achieved through the various practices shown in **Table 3**. For instance, simple measures such as taking the temperatures of employees could show whether any person is

TABLE 4 | Recommended practices to enhance communication and provide awareness.

Code	Practice
P7	Communicate about how the virus spreads
P8	Encourage employees who feel sick or are taking care of a sick family member to stay home
P9	Familiarize employees with testing sites close to the job site
P10	Host Q&As with healthcare professionals to clear misinformation about the virus
P11	Inform employees of flexibilities in paid leaves and sick times (if any)
P12	Keep everyone up-to-date on virus news
P13	Promote the safety of vaccines and benefits of immunizations
P14	Provide training on protection and prevention methods outside work
P15	Provide training on protection and prevention methods while working
P16	Remind employees continuously of the possible symptoms of the virus
P17	Respect employees' confidentiality and address the stigma on those who got infected

TABLE 5 | Recommended practices to ensure compliance.

Code	Practice
P18	Create a timely reward system for employees who adhere to safety laws, rewards can be intrinsic or extrinsic
P19	Create provisions to punish and penalize employees who do not adhere to the pandemic safety laws
P20	Enforce rules without distinguishing between vaccinated employees and those who are not
P21	Ensure that tasks are performed safely
P22	Observe the compliance of prevention methods including social distancing, hygiene, masks, and PPE.

sick and send them back home (P2). Screening can also be extremely important to identify possible exposures (P6). Screening questions can include whether the employee or any of their family members were in contact with an infected person, whether they were in contact with a person in the process of being tested for infection, whether they traveled outside the USA, whether they have been medically directed to self-quarantine, or whether they have been having trouble breathing or flu-like symptoms in the last 48 h. Moreover, maintaining site registers can assist in tracing possible exposures (P3).

Communication and Awareness

The objective of this theme is to enhance communication within the company and provide awareness on the virus. A total of 11 practices were identified under this theme, as shown in **Table 4**. For example, construction employers should promote COVID-19 awareness between employees, including methods of spreading, protection, and prevention from the virus (P7, P14, P15). Employees should also be familiar with all possible symptoms including fever, cough, shortness of breath, sore throat, chills, runny or stuffy nose, fatigue, or body aches (P16). Moreover, employers should keep employees updated on COVID-19 news and the plan for the vaccination, especially with the high amount of misinformation spreading about the virus (P12, P13). Employers can communicate with their employees through numerous means such as brief meetings, webinars, posters, signages, emails, social media groups, and regular toolbox meetings.

Compliance

The objective of this theme is to ensure safety and health compliance in the workplace. This overarching theme can be

achieved through the different practices shown in **Table 5**. For example, safety and health officers or safety site supervisors should be responsible to ensure that the workers adhere to the safety regulations to prevent possible exposures to the virus (P22, P23). Procedures to reward compliance and discipline non-compliance can be helpful (P18, P19). Moreover, getting the vaccine does not grant any employee the freedom to stop being cautious, as the risk of exposure and spreading the virus remains (P20).

Daily Tasks and Activities

This theme focuses on assessing daily tasks and activities to identify risks of virus exposure and eliminate or limit them as much as possible. As shown in **Table 6**, seven practices are identified for this theme. OSHA divided construction work tasks into three exposure risk levels: low, medium, and high (OSHA, 2021). Tasks with a low-level exposure risk are “tasks that allow employees to remain at least 1.83 m (6 ft) apart with little contact with public, visitors, or customers”. Tasks with a medium-level exposure risk are “tasks that require workers to be within 1.83 m (6 ft) of one another” or “tasks that require workers to be in close contact (within 1.83 m or 6 ft) with customers, visitors, or members of the public”. Tasks with a high-level exposure risk happen when employees “enter an indoor work site occupied by people such as other workers, customers, or residents suspected of having or known to have COVID-19, including when an occupant of the site reports signs and symptoms consistent with COVID-19”. OSHA’s classification can be very helpful in identifying what tasks need immediate attention (i.e., middle risk) and what tasks should be delayed (i.e. high risk).

TABLE 6 | Recommended practices to asses' daily tasks and activities.

Code	Practice
P23	Adopt a COVID-19 exposure control planning tool
P24	Avoid stacking of workforce trades whenever possible
P25	Conduct risk and hazard for potential virus infections
P26	Delay activities that are deemed non-essential with high exposure risks
P27	Identify employees who are vulnerable in tasks to extra take precautionary measures
P28	Limit sharing tools and equipment
P29	Minimize skin-to-skin works

TABLE 7 | Recommended practices to implement engineering controls.

Code	Practice
P30	Enhance ventilation rates in workplaces
P31	Increase outdoor air that circulates into the system
P32	Install high-efficiency air filters, and seal edges of the filter to limit bypass
P33	Install physical barriers such as protective divining screens
P34	Maintain humidity level between 40 and 70%

TABLE 8 | Recommended practices to implement an exposure response plan.

Code	Practice
P35	Adopt effective record keeping systems to trace contacts
P36	Create procedures to safely transport sick employees to their homes or healthcare facilities, whichever is needed
P37	Dedicate isolation areas for workers showing infection symptoms (if possible)
P38	Inform employees on possible virus exposure so they quarantine; but maintain confidentiality
P39	Keep a sanitization team on-hold to act aggressively in case of an exposure; outsource if necessary
P40	Monitor absenteeism at work
P41	Work with insurance companies and/or state and local health agencies to provide information on medical care in the event of a COVID-19 outbreak

Engineering Controls

The objective of this theme is to implement engineering controls in the workplace. Five practices are identified under this theme and are shown in **Table 7**. Major examples of engineering controls include physical barriers (P33), ventilation (P30, P31), and humidity (P34).

Exposure Response Plan

The objective of this theme is to create and implement a response plan in case of a possible virus exposure or if an employee develops symptoms during work hours. Practices supporting this theme are listed in **Table 8**. As the virus may be unpredictable, employers must put a response plan in case an employee is suspected to have been infected with COVID-19. The plan should include measures to isolate the employee (P38), safely transport the outside the workplace (P36) and sanitize (P39). Moreover, adopting an effective record-keeping system can be very helpful in tracing down employees who may have been exposed to the virus (P35, P40).

Human Interactions

The objective of this theme is to minimize human interactions as much as possible, which can be enabled through the various

practices shown in **Table 9**. Important practices in this category include altering shifts whether in sites or offices (P43, P44), altering breaks (P57), encouraging online meetings instead of in-person ones (P42, P49), and providing contactless communication like walkie talkies (P52). One important aspect to consider as well is to divide employees into small groups that are not interchangeable (P45). Group members in every team can be cross-trained to perform essential functions and provided with required alternative sources to facilitate works that require specific skills. Such a practice can be vital to limit virus exposure and decrease the risk of an outbreak. Moreover, dividing entrances between entrance and exits can minimize interactions, and adding more entrances can reduce congestion on screening and temperature checks (P48).

Hygiene and Sanitization

This theme emphasizes the need to maintain hygiene in the workplace, which can be achieved through the different practices shown in **Table 10**. For example, common contact surfaces such as tables, chairs, doorknobs, handrails, lift buttons, hoist buttons, handrails, ladders, and hand tools must be sanitized regularly (P70, P71). Hand washing facilities must be installed at convenient locations for all workers to access regularly and

TABLE 9 | Recommended practices to minimize human interactions.

Code	Practice
P42	Adopt digital conference software like zoom and teams
P43	Alter start and finish times on construction sites for different groups
P44	Alternate working in offices between different groups
P45	Consider dividing employees into small groups where group members are not interchangeable
P46	Encourage a “thumbs up” policy instead of hand shaking
P47	Identify employees who are at high risk of exposure and recommend they work from home whenever possible
P48	Increase access points whenever possible and designate them for “entry only” or “exit only”.
P49	Limit face-to-face meetings
P50	Maintain social distancing at all times, with a minimum of 1.83 m (6 ft)
P51	Maintain the use of stairs, lifts, and hoists
P52	Provide contactless communication to reduce close conversations
P53	Provide extra common areas like toilets whenever possible
P54	Restrict access to common areas like eating spaces and bathrooms based on their capacity to host safely
P55	Restrict non-essential visits and visitors and use virtual conference tools instead
P56	Shorten toolbox meetings
P57	Stagger break times to reduce congestion in common areas
P58	Use electronic paperwork instead of traditional ones (whenever possible)

TABLE 10 | Recommended practices to maintain hygiene.

Code	Practice
P59	Clean and sanitize toilet facilities regularly while restricting the number of employees using the facilities at the same time
P60	Disinfect offices, labor camps, toilets, canteens, pathways, entry gates, and exit gates daily
P61	Employ permanent sanitizing personnel (if possible)
P62	Encourage employees to not share personal belongings
P63	Encourage employees to wash their face and hands regularly for at least 20 s
P64	Install contactless payment methods whenever possible
P65	Install hand washing facilities at appropriate places convenient to workers
P66	Install non-bleach shoe sanitation tubs (if possible)
P67	Install no-touch garbage bins with biodegradable garbage beds in common access areas
P68	Provide extra bathroom facilities for employees to clean themselves before leaving (if possible)
P69	Provide prepared and wrapped food only when catering is provided
P70	Sanitize and disinfect tools, machines, and equipment whether they are shared or not
P71	Sanitize common contact surfaces on a regular basis
P72	Sanitize common surfaces of vehicles

TABLE 11 | Recommended practices to manage and handle deliveries.

Code	Practice
P73	Adopt a screening system for arriving deliveries
P74	Adopt digital signatures whenever possible
P75	Assign a limited number of people to handle materials and storage rooms
P76	Coordinate with suppliers to minimize contact and human interactions
P77	Dedicate an area, if possible, to store materials that have not been sanitized
P78	Install sanitization booths if possible
P79	Store papers and important documents in quarantine boxes before sending them to their destined receivers

safely, while being provided with extra supplies of soap, hand sanitizer and paper towels (P65). Disinfection and sanitization procedures should be also applied to common vehicle surfaces such as gear shifts, steering wheels, and instrument panels.

Management of Deliveries

This theme aims to manage and handle deliveries safely and avoid possible virus exposure and includes a set of practices as outlined in **Table 11**. Under this theme, employers should develop special

systems to handle material and equipment delivery, especially since the virus can stay on surfaces for days. Plans should include coordinating with suppliers for touch free deliveries and keeping drivers in their vehicles (P76), dedicating special areas with limited access to a number of employees (P75, P77), and sanitizing materials and equipment (P78). Another important aspect is that any paper used in the delivery process—especially if electronic signatures and receipts are not an option—should be placed in quarantine boxes before sending to the correct

TABLE 12 | Recommended practices to ensure physical and mental health.

Code	Practice
P80	Anticipate and monitor behavior changes in employees
P81	Avoid discrimination and building risk assumptions based on race or country of origin
P82	Build resilience and manage job stress
P83	Decrease workloads and extend deadlines whenever possible
P84	Host Q&As with managers regularly so employees can ask questions and discuss concerns
P85	Maintain privacy when health screening employees
P86	Make sick leave policies more flexible
P87	Provide guidance and tips for workers to work in a healthy manner whether at home, in offices, or on sites
P89	Provide guidance on fatigue management
P90	Provide resources for dealing with stress and anxiety related to the pandemic
P91	Talk openly and honestly about the effect of the pandemic on the company

TABLE 13 | Recommended practices to provide safety wearables and carry-ons.

Code	Practice
P92	Equip sanitization stations with hand soap, hand rubs disinfectants, and disposable paper towels
P93	Provide and mandate the use of masks
P94	Provide eye protection
P95	Provide disposable gloves instead of reusable ones whenever necessary
P96	Provide hand sanitizers with at least 70% alcohol
P97	Provide hazmat suits for high risk individuals and vulnerable workers whenever necessary
P98	Provide KN95/N95/FFP2 masks for high-risk areas and activities
P99	Provide sanitization packs including disinfecting wipes, hand soap, and alcohol-based hand sanitizers
P100	Sanitize reusable PPE according to manufacturer's documentation and dispose the non-reusable PPE adequately

personnel because the virus may be on the papers and can thus spread (P79).

Physical and Mental Health

The objective of this theme is to care for the physical and mental health of the employees. Employers need to understand that a pandemic can add work and home related stress due to different factors. CDC lists the following as potential sources of added pressure on the employees: “concerns about being exposed to the virus at work”, “lack of access to the tools and equipment needed to perform the job”, “conflicts at home”, “failure to take time to relax”, “feelings that you are not contributing enough to work”, “feeling guilty about not being on the frontline”, “uncertainty about the future of your workplace and/or employment”, and “adapting to a different workspace and/or work schedule” (CDC, 2021). Additionally, other factors like finances and worrying about vulnerable family members can aggravate the situation. Thus, the practices shown in **Table 12** play a major role in caring for the physical and mental health of the employee.

Safety Wearables and Carry-Ons

The objective of this theme is to provide and manage safety wearables and carry-ons to protect and shield employees from the virus. This theme is illustrated through the various practices shown in **Table 13**. Examples of wearables include masks and PPE like gloves, boots, eye protection, face shields (P93, P95). Examples of carry-ons include sanitizers, wipes, and hand soaps (P94, P96).

CONCLUSIONS, LIMITATIONS, AND FURTHER STUDIES

As researchers have been investigating the impacts posed by the global health threat COVID-19 on the construction industry and the guidelines developed to help fight the outbreak, there has been limited discussions on the concerns of construction workers—a group whose daily lives have been impacted. Using construction workers complaints collected through the OSHA Complaint tracker tool between March 1st, 2020 and January 18th, 2021, this study analyzed the reported complaints and outlined 100 health and safety practices to tackle the concerns of the construction workforce.

The analysis of the OSHA database showed that construction-related complaints were mainly reported in the states of California, Oregon, and Indiana. Complaints peaked in March and April of 2020 then decreased gradually. Almost half of the complaints were related to the Construction of Buildings category of work—specifically nonresidential building construction. The other half was related to Specialty Trade Contractors, notably building equipment contractors such as Mechanical, Electrical, and Plumbing (MEP) subcontractors. Half of the construction-related complaints were filed using the phone, and the majority of the complaints were deemed non-formal. Regarding the nature of the complaints, most construction workers voiced concerns over personnel who tested positive to the virus or were exposed to COVID-19 and kept reporting to work; employees were not abiding by mask mandates; and employees were not taking

precautions, enforcing social distancing, and providing masks and PPE.

To mitigate the concerns, the author then reviewed the existing research corpus and the guidelines set by three major safety and health agencies—namely OSHA, CDC, and AGC—and compiled a list of 100 best practices. The practices were divided into 11 themes: access points, communication and awareness, compliance, daily tasks and activities, engineering controls, exposure response plan, human interactions, hygiene and sanitization, management of deliveries, physical and mental health, and safety wearables and carry-ons. It should be noted, however, that while the reviewed guidelines outline recommendations for best practices, as new information about the virus and its spread comes to light, OSHA, CDC, and AGC are continuously updating their guidelines to account for the changing environment.

The study does come with some limitations. The nature of the analysis performed in this paper was qualitative descriptive, therefore, future work can employ statistical techniques to test hypotheses and correlate the health and safety concerns of construction workers to the performance of construction projects. Additionally, the analysis was performed for the period between March 1st, 2020 and January 18th, 2021 and therefore, the results do not provide insights into how the COVID-19 situation is unfolding among the construction

workers as the vaccines are being rolled out. Moreover, while 100 health and safety practices were synthesized, the author recognizes that not all 100 practices are equally effective. Therefore, future study can assess the effectiveness of these practices as well as other practices that may be implemented depending on how the COVID-19 pandemic evolves on the jobsite.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: <https://www.osha.gov/foia/archived-covid-19-data>.

AUTHOR CONTRIBUTIONS

MB: conceptualization, resources, methodology, formal analysis, discussion, visualization, writing - original draft preparation and visualization. AF: resources, formal analysis, discussion, writing - original draft preparation. HN and HS: writing - reviewing, editing, and administering the paper. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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