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Original Article

Assessing the Effect of Quality Based Factors on the Compliance Level of Quality Control and Concrete Waste Management in Buildings Construction-Case Study of Kenya

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Abstract *- Low compliance with quality control practices has resulted in more buildings collapsing during or shortly after construction and increased demolitions across the Kenyan construction industry. This has increased the concrete waste generation rate, and project cost overrun. Improved solid waste generation from construction has deemed existing waste management frameworks ineffective in curbing the amount of waste generated. Concrete solid waste dominates construction and demolition waste, demanding exploration of viable methods to reduce or prevent its generation, given that concrete is among the most utilized construction materials with both cost and environmental impacts. The study used a cross-sectional descriptive survey to evaluate the effect of quality control-related factors on the quality control and concrete waste management level of compliance. Qualitative and quantitative data were collected through questionnaires, on-site observation checklists, interviews with construction professionals, and reviewing relevant documents and records. Descriptive statistics and inferential statistical analysis were used to analyze the data. The potential influence level of quality factors evaluated was high, with post-cast, formwork, and pre-finish quality factors statistically significant in causing concrete waste generation and with their frequent occurrence affecting the level of compliance negatively. The researcher recommends that building contractors employ a quality control-based approach to managing resources to reduce or prevent waste. The study results can be implemented by enforcing the inclusivity of this approach by contractors while submitting their compliance reports to environmental regulatory bodies assessing waste management compliance.*

Keywords *- Compliance level, Concrete waste, Management, Quality control, Quality factors.*

1. Introduction

Waste generation in the construction industry has been massively growing at an alarming rate due to defects in the structures related to poor quality control in conventional and modern construction. As of 2021, Construction and Demolition (C&D) waste was estimated to have dominated the market with a market share of 23% and market revenue of 7.4 billion USD. The overall waste from construction reached a market size of 55.54 billion dollars [53]. Unfortunately, the increased usage of concrete also results in more waste, a global issue. Among the causes of ongoing carbon dioxide emissions into the atmosphere are the manufacture of cement and the generation of C&D waste. According to [18], between 1.5 and 3.0 tons of concrete are produced annually per person in the industrialized world.

According to [2], more than 3.0 billion tons of C&D debris were produced annually in 40 nations till 2012, and this number is steadily rising. The proportion of concrete waste in all construction waste produced in Kenya is around 15%, with much of it incorrectly disposed of [12]. According to [51], the increased amount of concrete waste is directly proportional to concrete production, and the building areas of demolition and construction induce substantial waste in building construction.

While most building constructions heavily rely on concrete as a construction material, most C&D waste is made of concrete [8]. Concrete waste and other C&D wastes are produced for a variety of reasons, including poor workmanship, design modifications, poor design and specifications, ambiguous information, poor planning, lack of control, improper storage, communication issues, hostile project participants, a lack of some information in the drawings, damage during transportation, purchase of substandard and ordering mistakes [36, 40]

The waste management practices of recycling and reusing concrete waste in the construction industry are inefficient [13]. The global market for recycled construction waste is at 4.7 billion USD, and it's expected to rise to 6.2 billion USD by 2027 [54]. 15-20% of C&D waste is recycled, about 10% is reused, and the rest, 70%, is disposed of globally [13]. Consequently, the cost and time of reusing and recycling construction waste hinder waste management options [2].

Despite having many alternatives to managing C&D waste, construction waste generation continues to increase at an alarming rate, with concrete-related waste taking the lead. Since it's impossible to completely do away with concrete as a construction material, improving the existing construction management procedures will help reduce the waste generated from construction [21].

Even with increased initiatives to slow down the depletion of natural resources, it is nearly impossible to prevent it entirely; hence, sustainability in construction materials selection, manufacturing, and waste management must be considered when designing various construction projects.

In the report by Kenya National Housing Corporation (KNHC) on the Construction Industry Development Policy (2018), various challenges, including poor quality of work geared by poor workmanship and use of substandard materials, inadequately skilled and incompetent workforce, and lack of standard monitoring and evaluation framework roam the local building construction industry. The failure associated with building construction activities has often been linked to poor quality control [3, 26].

It's alarming that about 10-20% of the total concrete used for construction construction forms concrete waste with quality control in place [4, 7]. In Kenya, conventional and modern methods are subject to poor quality control, leading to buildings collapsing, unending reworks, and increased C&D waste generation, which is finding its way into illegal dumpsites. According to [27], most building contractors in Kenya do not follow a strict quality control system, resulting in poor quality concrete and poor workmanship, hence concrete waste generation from reworks, demolitions, and collapse of buildings.

Quality control ensures compliance with minimum standards of material and workmanship to ensure the facility's performance as per the design. Regardless of its need, quality control in the Kenyan construction industry has been confined to massive complex projects, and the quality of small vital projects' quality is being decided without a structured plan or approach.

Furthermore, quality control ensures that the structure being erected serves its purpose without compromising its occupants' target needs and requirements but, in many instances, does not ensure construction efficiency and sustainability related to environmental protection and resource optimization. As a result, this increases demolition works on building construction sites [1] to meet the design and customer requirements. The failure to adhere to procedures increases construction defects, cost, and environmental problems from concrete waste generation [26].

The duration of building erection, increased civil engineering work, and the need for high-quality operations are the driving forces for the urgency of modern construction. If not well regulated, the rapid construction of buildings jeopardizes quality. In the construction of buildings, inadequate quality control and defective formwork have been linked to the causes of final product flaws.

According to [30], the elements of shuttering structures can develop defects that cause inflows, shells, and engravings on the structure's surface, as well as deviations from the design dimensions of structural elements, exceeding maximum permissible values, and deviations from the verticality of the building structure. Modern prominent formwork manufacturers, including KUMKANG KIND, DOKA, MIVAN, and PERI, are continually working to improve formwork systems for efficiency in building construction. However, the efficiency of modern technologies is not guaranteed locally, where the experience in their use is insufficient. The technologies face various challenges, such as requiring skilled labour, special worker training, difficulties in repairs and maintenance, and high initial investment costs [30].

Human errors related to poor planning and design inadequacies of the building result in overestimating the required concrete, construction errors and defects that require reworks and demolitions, leading to concrete waste generation [23, 56]. The type of formwork and formwork material, the removal time of formwork, reuse of formwork, formwork maintenance and design capacity significantly affect the amount of concrete waste generated during or after casting.

[3, 19] reports that formwork failure during casting is caused by overloading the formwork system beyond its designed capacity, primarily due to inexperience. Furthermore, most structural demolitions are attributed to the

failure of construction materials. This is a quality control issue as it should always be ensured that the material and workmanship during construction are per the required standards and quality. Poor-quality reinforcement weakens the structure and causes costly repairs, eventually contributing to concrete waste generation.

Removing defective elements and the requirement to repair MEP ducts are also significant sources of concrete waste in construction projects. Cast-in-place building constructions frequently produce indirect substantial waste, such as waste from concrete walls or slabs that are thicker than intended as per the structural design [11].

According to [34], errors in management, design and documentation lead at 66% as the significant causes of waste generation, followed by human errors at 64%. Errors in construction methods and procedures rank third at 60%, and construction materials management ranks fourth at 59% in contributing to waste generation.

Reworks of defective components uncovered during finishing, maintenance, and other post-building activities lead to a 6–15% construction cost escalation [21]. Concrete waste generation has also been linked to failure and defects arising from poor workmanship. 20-40% of all site defects originate from construction-related mistakes. In comparison, 54% of construction faults can be ascribed to human factors like inexperienced labour or inadequate project supervision, while failures of the materials and systems account for 12% of building problems [35].

Hence, improving the inspection and quality system in construction is essential. Measurements and testing techniques should be used to establish the quality objectives throughout the planning stages. Quality issues will decrease whenever project participants know what is required of them from the start to attain quality [35].

Quality control of concrete material, concrete placement in the forms, work inspections, and workforce training reduce the number of flaws that create substantial waste. Additionally, repairs and changes that take a long time to complete delay the job and cause an additional financial impact on the project and, consequently, waste generation [42].

The building construction industry in Kenya has been experiencing significant growth in recent years, leading to increased construction activities and consequently generating substantial amounts of waste, including concrete waste. The construction market size was about 17.3 billion in 2022, and the growth projections are more than 5% and 4% for commercial and industrial constructions between 2024 and 2027 [14].

[1, 34] recognize that there is a need to identify the most effective quality control practices and to develop guidelines that can help contractors and project managers implement these practices more effectively and ensure that waste generation in the construction industry is minimized while optimizing the existing management practices. While fast-building construction techniques are becoming common, there is a need to research the impacts of inefficient quality control practices in concrete construction, resulting in substantial waste generation [30, 43].

Research is needed to identify quality control issues by assessing the status of quality control systems in building construction that aim to develop more sustainable solutions that mitigate the impacts of waste generation issues, especially the dominant C&D waste, concrete [35, 57].

This study sought to assess the level of compliance with quality control and concrete waste management in the construction of buildings. From the study, the assessment should provide a vivid understanding of concrete waste generation factors and how they influence concrete waste management and quality control. Proper concrete waste management is crucial to mitigate environmental impacts, optimize resource utilization and reduce construction costs.

The assessment of quality control and management of concrete waste in the construction of buildings was done within the context of Kenya’s building construction industry. The study cut across Kenyan counties to evaluate the influence of quality control factors in generating concrete waste and their effect on the quality requirements. Through a comprehensive analysis of building construction sites, waste management protocols, and stakeholder perspectives, the research aimed to provide valuable insights into improving the level of quality control related to concrete material and concrete waste management strategies in Kenyan construction projects. Data was collected through surveys, on-site observations, interviews with project managers, construction workers, and waste management personnel, and a review of relevant documents and records.

2. Materials and Methods

A cross-sectional descriptive survey was adopted to assess the factors from professionals responsible for the construction of buildings at various building construction sites in Kenya. This design allowed data collection from a sample of individuals simultaneously.

Survey questionnaires and observation checklists were used. The target population typically comprises construction professionals such as construction technicians, quantity surveyors, architects, civil engineers, work inspectors, site supervisors, quantity surveyors, and construction managers, as categorised in Table 1.

Table 1. The target population for the study indicating the sample size from each category calculated using Yamane's formula

Target Population	Professional Body	Total Number	Sample Size
Professional Civil Engineers	EBK	1571	96
Consulting Civil Engineers	EBK	403	60
Professional Architects	BORAQS	987	85
Professional Quantity Surveyors	BORAQS	624	73
Professional Technicians	IET (Kenya)	3340	107
Total		**6925**	**421**

Source: EBK, BORAQS, IET(Kenya) Websites

Building contractors were drawn from categories 1 to 5 according to NCA ranking, making multi-stage sampling suitable for the application, as shown in Table 2. It was essential to include both large categories of building contractors in the industry, capturing small- and medium-sized enterprises.

Questionnaires are simple and efficient in extensive population data collection and data coding and interpretation [37]. Questionnaires seeking to evaluate the influential factors related to quality control were administered to the respondents by visiting various construction sites. Cumulatively, a total of 47 questions (grouped into five categories as formwork, concreting, post-cast, human error and pre-finish quality factors) sought the extent to which respondents agreed that influential factors have frequent occurrence on a Likert scale of 1 to 5.

Table 2. The sampling frame for the building contractors within the NCA categories 1 to 5 considered for the study

NCA Category	Building Contractors
1	546
2	429
3	693
4	2,169
5	2,391
Total	**6228**

Source: NCA Website

A total of 421 professionals determined by Yamane's Equation 1 were purposively sampled from the population of registered professional civil engineers, consulting civil engineers, professional architects, professional quantity surveyors and professional technicians to provide the data for the study, as shown in Table 1.

$$n = C\left(\frac{N}{1 + Ne^2}\right) \tag{1}$$

Where, n is the contractor's sample size, N is the total number of construction professionals, C is the coefficient of variation taken as $C = 30\%$, and e is the margin error taken as 5%.

A representative sample of 43 respondents among the target population was selected for the pilot study. The respondents were given a week to respond to the questions. A total of 32 responses were received. The data obtained was then analyzed to identify insufficiencies of the instruments. An improved questionnaire was then administered to the same number of respondents who had initially responded. A total number of 30 responses were obtained after a week. Pearson's correlation coefficient (r) value of 0.89 indicated a satisfactory test-retest reliability of the questionnaire.

After improving the questionnaire and retesting, Cronbach's alpha value was above 0.8, making the scale reliability suitable, as shown in Table 3. According to [9], Cronbach's alpha is acceptable, but a coefficient greater than 0.8 is preferred to ascertain the reliability of the scale used.

Table 1. Cronbach's alpha value for checking the internal consistency of the scale used in the questionnaires for data collection

Cronbach's Alpha ($\dot{\alpha}$)	Internal Consistency
Above 0.9	Excellent
0.8 - 0.9	Good
0.7 - 0.8	Acceptable
0.6 - 0.7	Questionable
0.5 - 0.6	Poor
Less than 0.5	Unacceptable

Source: Salkind, 2015

From the total sample size, 328 (78%) responded to the questionnaire from construction sites visited. The response rate from the contractors under the NCA-1 category was 39%, followed by NCA-2 (21%), NCA-5 (16%), NCA-3 (16%), and NCA-4 (7%) as shown in Figure 1. From [55] meta-analysis on response rate, most social research had an average of 44.1% with a 95% confidence interval. This is subject to various factors influencing the response rate, such as the project's funding status and the participants' age and occupation. A response rate of 78% from this study was way above average and acceptable for social science-based research.

In terms of experience in the construction industry, 77% of the respondents had over five years of experience, and only 2% had less than one year of experience, as shown in Figure 2. More than 67% of the respondents had attained a graduate level of education. In terms of experience in the construction

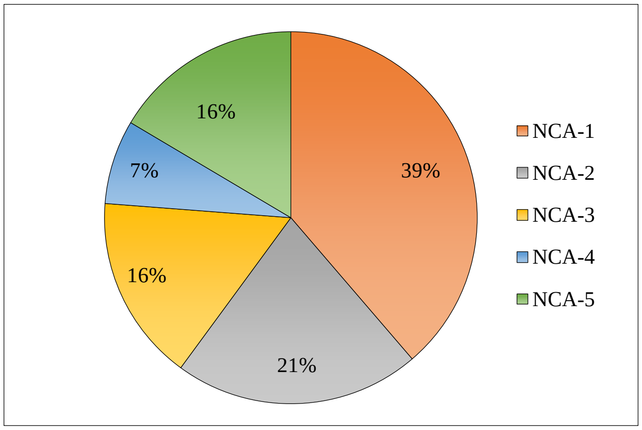

Fig. 1 The response rate from NCA categories of NCA 1 to NCA 5

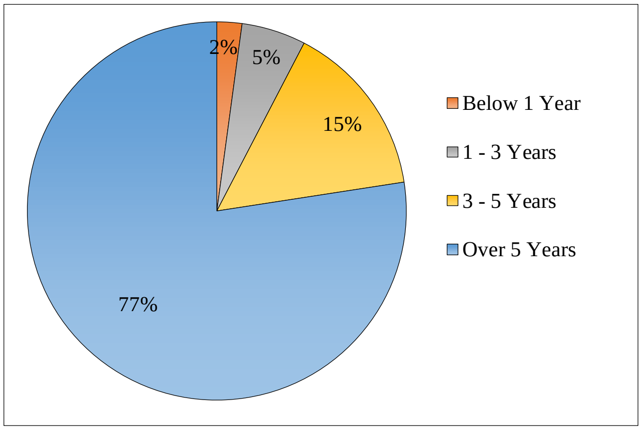

Fig. 2 The level of experience of the respondents involved in the study

77% of the respondents had over five years of experience, and only 2% had less than one year's experience, as shown in Figure 2. More than 67% of the respondents had attained a graduate level of education. According to [58], the level of education influences the response rate and determines the quality of responses as literate participants understand the study's requirements vividly.

This is the same effect with the experience level of the respondents in their specific roles as more experienced participants respond more correctly to the questionnaire than the less experienced participants. Therefore, the reliability of the information gathered was adequate and accurate to consider for analysis.

The highest category of respondents was foremen (28%), followed by site engineers or supervisors (15%). Quality control personnel were represented by 5%, which was very low compared to the expected number, as shown in Figure 3.

More responses were recorded from the foremen, who constantly monitor all the construction processes. Data was collected from 27 counties across the country, with Kiambu and Nairobi City counties leading in the number of sites visited at 12% and 11%, respectively, as shown in Figure 4. A report by [28] on an economic survey depicts more building construction activities in Nairobi City County and its surrounding environments (Kiambu and Machakos counties) than in other counties in Kenya.

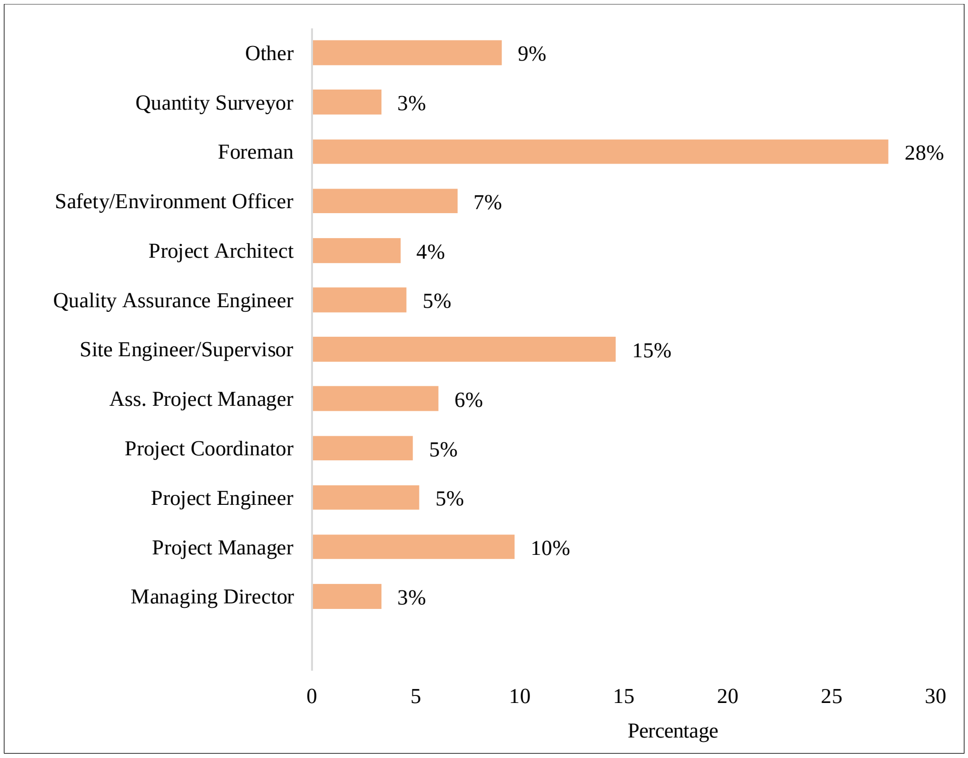

Fig. 3 The roles of various respondents that were involved in the study

Fig. 1 Response percentage from the 27 counties where data was collected

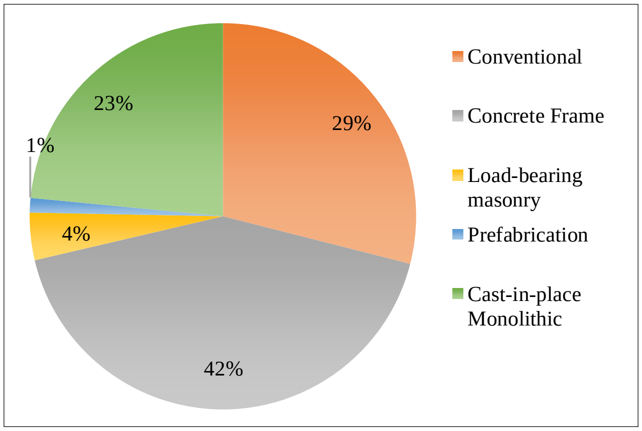

Fig. 2 Types of construction techniques employed at various sites where data was collected

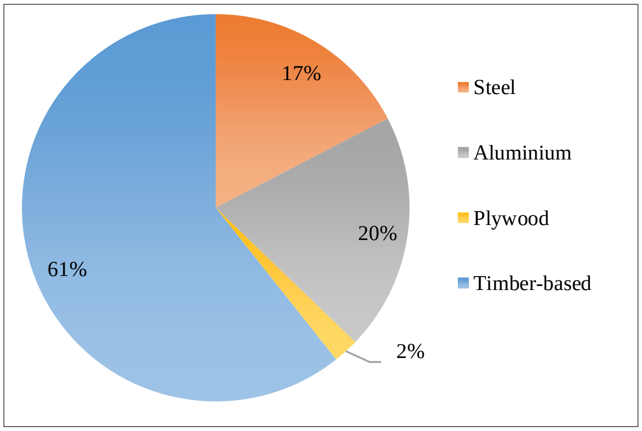

Fig. 3 Different formworks used for concrete casting at various construction sites visited to construct buildings

Among the sampled projects, 42% employed concrete frame construction techniques, 29% employed conventional methods, and 23% employed cast-in-place monolithic construction techniques, as shown in Figure 5. With the concrete frame, cast-in-place monolithic and conventional techniques taking the lead as the most preferred methods; it was evident that the consumption of concrete in the building construction industry is very high in Kenya.

Among the building construction projects sampled, 61% used timber-based formwork in their construction work involving concrete, 20% used Aluminium formwork, steel formwork (17%), and plywood-based formwork (2%), as shown in Figure 6. Formwork-related activities account for about 75% of the time spent on constructing reinforced concrete structures [52]. According to [46], the type of formwork also determines the total project cost in terms of its durability (reusability and ability to sustain loading) and waste generation.

The level of application and compliance of the quality control and concrete waste management practices were determined using frequency indices and a hypothesized one-sample t-test. This was determined by assessing the status of quality management, on-site material and work quality control inspections, the experience level of quality control personnel, quality tests and quality audits. The compliance assessment also sought the application level of quality control techniques, on-site waste management practices, and compliance with waste management regulations.

The impacts of the influential factors, which included formwork, human error, concreting, post-cast and prefinish quality factors, were determined by categorizing and ranking the factors using the frequency indices, Significance Potential Values (SPVs) and regression analysis to determine their effect on the compliance level using the ANOVA analysis at 95% confidence interval by testing the null hypothesis.

H_o: The assessed factors do not significantly influence the level of quality control in the construction of buildings and concrete waste management. $\beta_i=0$, i.e., $\beta_1= \beta_2= \beta_3=\beta_4= \beta_5=0$.

H_a: The assessed factors significantly influence the level of quality control and concrete waste management in the construction of buildings. $\beta_i\neq0$, i.e., at least $\beta_1\neq \beta_2\neq \beta_3\neq \beta_4\neq \beta_5\neq0$.

A model showing the magnitude of each factor's category was then developed, as shown in Equation 2. All the steps were performed using the SPSS software.

$$Y = \beta_0 + \beta_1 Q1 + \beta_2 Q2 + \beta_3 Q3 + \beta_4 Q4 + \beta_5 Q5 \quad (2)$$

Where, Y represents the dependent variable, level of compliance, β_0 is the intercept term, Q1 is formwork control factors, Q2 is concreting quality factors, Q3 is post-cast quality factors, Q4 is human error factors, and Q5 is prefinish quality factors. β_1, β_2, β_3, β_4, and β_5 are the corresponding coefficient of the factors.

Collecting data from construction sites and administering the questionnaires to the industry professionals were conducted with a legal license from the National Commission for Science, Technology & Innovation (NACOSTI). An introduction letter from the Institute and the NACOSTI license accompanied the questionnaires to prove compliance with the data collection Act, confidentiality, anonymity, privacy, dual use and respect for autonomy. All these documents clearly explained the purpose of the information required by the respondents.

3. Results and Discussion

3.1. The Level of Compliance of Quality Control and Concrete Waste Management

The analysis was performed in SPSS software, and the statistic results were checked for the significant values in the t-distribution table (H_o: $\mu > \mu_m$, upper-tailed; H_a: $\mu < \mu_m$, lower-tailed; μ_m = hypothesized mean and μ = sample mean).

To apply t test, the mean, standard deviation, sample size, and population hypothetical mean value are used, and the sample should be a continuous variable and normally distributed. According to [38], if the population standard deviation is unknown, the one-sample t-test can be used at any sample size. The data's mean value was 2.499, which was below the hypothesized mean of 3.

According to [31], the difference will be close to zero if there is no difference in the two-sample means. Therefore, in such cases, an additional statistical test should be performed to verify whether the difference could be said to be equal to zero.The t-test determined whether the population mean was statistically below or above the hypothesized mean (one-tailed t-test). The critical t-statistic value from the probability t-distribution table for the one-tailed test was -1.645 at a 0.05 significance level, and the t-statistic value -27.523, 327 is shown in Figure 7.

The one-sample t-test performed in SPSS software at 95% Confidence Interval (CI) and for n-1 degree of freedom depicted that the p-value was less than 0.001 and lower-tailed, indicating that the sample mean was significantly less than the hypothesised mean, as shown in Table 4. The analysis results presented significant evidence to statistically reject the null hypothesis that there is a low compliance level of quality control and management of concrete waste in the construction of buildings.

According to [47], when the normality assumptions are violated, inferences and interpretations of the statistical results may not be reliable. Their study comparing different statistical tests found that the Shapiro-Wilk test performs better than Anderson-Darling, Kolmogorov-Smirnova and Lilliefors for symmetric distributions. The test for normal distribution was satisfactory, as shown in Table 5, as the p-values for the Shapiro-Wilk statistic were more significant than 0.05.

Table 2. One sample t-test analysis for the compliance level of quality control and concrete waste management

Test Value = 3						
Compliance Level	**t-Statistic Value**	**Degree of Freedom**	**P-Value (Lower-Tailed)**	**Mean Difference**	**95% CI of the Difference**	
					Lower	Upper
	-27.523	327	<0.001	-0.501	-0.537	-0.465

Table 3. Test for normality of the sample

	Kolmogorov-Smirnova			**Shapiro-Wilk**		
Compliance Level	**Statistic**	**df**	**P-value**	**Statistic**	**df**	**P-value**
	0.039	328	0.200	0.992	328	0.069
This is a lower bound of the true significance lilliefors significance correction applies						

3.2. Quality Control Influential F1actors Evaluation

3.2.1. Quality Factors Potential Influence and Ranking

Then, mean and frequency index was used to rank the factors with the most influential ranked first, and the least influential factors ranked last, determined using Equations 3 and 4, respectively. The significance potential values were used to rate the potential influence level of the factors, interpreted as shown in Table 1 and calculated using Equation 5.

$$\mu = \sum_{1}^{5} a_i n_i \tag{3}$$

$$FI = \frac{\sum_{1}^{5} a_i n_i}{5} \tag{4}$$

$$SPV = FI \times 100 \tag{5}$$

Where is the mean, FI is the frequency index, SPV is the significance potential value, a is the weight assigned to each response i, n is the frequency of each response i, N is the total number of responses, and 5 is the highest weight given to the choices.

The factors assessed were based on the quality control aspects, as shown in Table 3. According to [41], construction waste generation factors include non-physical and physical characteristics. In both categories, frequent design changes, worker mistakes during construction, poor planning and control, and ordering mistakes exist, with a higher potential to cause waste generation.

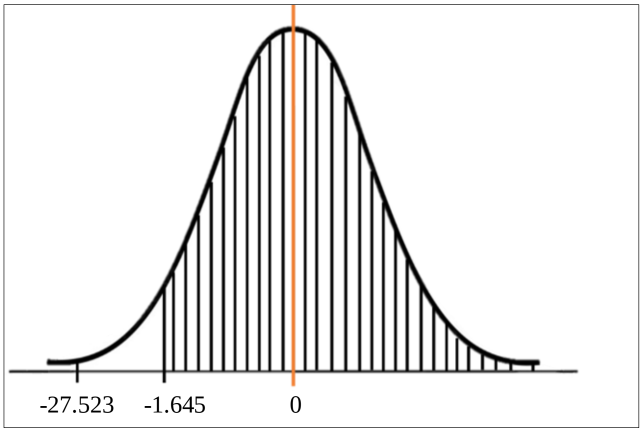

Fig. 4 The significance of the t-statistic value defining the region of rejection and region of acceptance of the null hypothesis on the level of compliance

Various factors lead to concrete waste generation, such as excessive ordering, overfilling of forms, broken forms, reworks due to poor quality control, lack of experience of the workers, and purchase of substandard materials [25, 33, 39]. This study assessed the quality control factors related to formwork conditions, post-cast defects, human errors, concreting, and corrective prefinish factors.

Table 4. The potential influence level is dependent on the scale range used for questionnaire responses, including the range of Significance Potential Values (SPVs) for influential factors potential interpretation

Scale Range	SPVs	Potential Influence
1.00 – 1.50	20 – 30%	Very Low
1.51 – 2.50	31 – 50%	Low
2.51 – 3.50	51 – 70%	Medium
3.51 – 4.50	71 – 90%	High
4.51 – 5.00	91 – 100%	Very High

Source: Bringula et al. 2012

All these factors mature into causes of concrete waste when quality planning and control are not observed. The assessed factors' influence level was interpreted as shown in Table 6.

A variety of things affect the formwork's quality. The correctness and level of development of technical documentation, compliance with technological discipline, careful use of the formwork and monitoring of the condition of all constituent elements of the formwork system, compliance with the materials from which the formwork is made, and worker qualifications.

Formwork systems comprise numerous structural components; thus, it is important to understand how the characteristics of each one affect the system's overall reliability, the ability to do this kind of work, and the quality of the final building. Quality control procedures as highlighted must be in place to guarantee that all activities are in compliance.

Among the formwork quality factors assessed, poor stripping of formwork panels (Rank 7; SPV 56%) and overuse of formwork panels (Rank 8; SPV 55%) had the highest potential to cause generation of concrete waste compared to other formwork quality factors as shown in Table 8. Formwork failure during casting (Rank 41: SPV 27%) and formwork oil misapplication (Rank 45; SPV 23%) had the lowest potential influence as their SPVs were below 30%. The rest of the formwork quality factors had SPVs between 30% and 50%.

Concrete material quality control testing helps ensure that the concrete used in construction meets the required strength and durability specifications. This can enhance the structural stability of the building and reduce the risk of structural failure. These controls also help to identify and correct issues with the materials before they are used in construction.

This has been reported to reduce the risk of defects and failures in the building and improve its overall quality. Fresh concrete segregation (Rank 9; SPV 51%) and poor vibration of concrete (Rank 10; SPV 51%) were the most influential factors under concreting quality factors, while the rest of the factors had SPVs greater than 30% and less than 50%. Fresh concrete properties greatly depend on the water-cement ratio, the amount and type of aggregates used, the type and amount of cement used, and the addition of any admixtures. To curb the issues related to fresh concrete, the above parameters must always be checked, and concrete production and placement workmanship must be monitored.

From the analysis, it was clear that post-cast quality factors had the first three ranked factors with the high potential to cause concrete waste generation, including concrete cracks (Rank 1; SPV 75%), honeycombing (Rank 2; SPV 75%), and uneven concrete surface after casting (Rank 3; SPV 61%). Nevertheless, the deviations and errors in the dimensions in the cast design elements (Rank 39; SPV 28%) had an SPV lower than 30%, as shown in Table 8.

Human error factors on how concrete is handled indicated that rejection of supplied ready mix concrete (Rank 4; SPV 59%) and improper transportation of concrete during casting (Rank 5; SPV 59%) contributed more as factors causing generation of concrete waste as they ranked fourth and fifth overall as shown in Table 7. The use of faulty pouring equipment (Rank 46; SPV 18%) and poor workmanship in handling concrete (Rank 47; SPV 16%) had SPVs less than 30%.

Among the pre-finish quality factors assessed, reinstatement of reinforcement (Rank 6; SPV 58%) had the highest potential influence, while removal of contaminated concrete (Rank 38; SPV 28%), hacking of misaligned elements (Rank 40; SPV 28%) and design changes (Rank 43; SPV 26%) had SPVs less than 30%.

When concrete elements and surfaces are not to standards as per the quality demand, this leads to reworks that involve demolitions and reinstatements that lead to the generation of unnecessary concrete waste. Formwork quality factors ranked fourth. Formwork is the most crucial element of concreting works as it defines the final product metrics affecting the quality specifications [19]. The failure to control formwork defects and formwork installation leads to concrete waste generation, both fresh concrete and demolished substantial waste [24].

The study by [29] indicates that the damage to materials on site, double handling of materials and incompetent contractor's technical staff were the most significant factors. Concreting quality factors came second, indicating that the amount of unused fresh concrete waste is significantly due to poor-quality concrete used on various building construction sites [27]. Human error factors ranked fifth. These factors are likely to cause the generation of fresh concrete waste as they involve workmanship, management, and procurement errors [1, 11].

3.2.2. Regression Model Evaluation

The regression involved predicting the effect of quality control and concrete waste management compliance by the formwork quality factors, concreting quality factors, post-cast quality factors, human error factors and prefinish quality factors. The model validation was by testing the null hypothesis (H_0: $\beta_i=0$, i.e., $\beta_1= \beta_2= \beta_3=\beta_4= \beta_5=0$; Ha: $\beta_i\neq0$, i.e., at least $\beta_1\neq \beta_2\neq \beta_3\neq \beta_4\neq \beta_5\neq0$).

Variables Correlation Analysis

Variables correlation analysis was performed using Spearman's rank order correlation. A Spearman rank correlation describes the monotonic relationship between two variables. It is helpful for nonnormally distributed continuous and ordinal data and is relatively robust to outliers [49].

The correlation between post-cast quality factors and the compliance level was the highest (0.602) among the independent variables, followed by concreting quality factors (0.453), then human error factors (0.429), followed by formwork quality factors (0.357) and finally the finish quality factors (0.307) as shown in Table 11.

Multicollinearity Test

The degree of correlation among the regression model independent variables has to be evaluated to meet the multicollinearity requirement. In a multiple-regression model, if one explanatory variable is the same as another independent variable and exhibits a strong correlation coefficient, it indicates the presence of multicollinearity. Typically, these variables contain comparable information for predicting the dependent variable, leading to the redundant inclusion of similar variables in the model.

According to [50], multicollinearity complicates the identification of the correct predictive variable in a study, as accurate estimation of partial regression coefficients becomes challenging, leading to elevated standard errors. This indicates a reduction in the information content of the independent variables.

The degree of correlation among the regression model independent variables has to be evaluated to meet the multicollinearity requirement. The Variance Inflation Factor (VIF) equal to 1 is considered null, implying that there is zero multicollinearity, a VIF between 1 and 5 indicates a very low level of multicollinearity, and a VIF above 5 indicates high multicollinearity between the independent variables [10, 15, 50].

The VIF for the independent variables used in this study was very low, with VIF ranging from 1.222 to 2.038; therefore, their multicollinearity was low, making them viable for the regression model as model predictors. Table 7 shows the VIF values for the independent variables calculated using SPSS software.

Table 7. Variance Inflation Factor values for the influential factors testing the multicollinearity of quality factors as independent variables in a regression model

Collinearity Statistics		
	Tolerance	VIF
Formwork Quality Factors	0.687	1.455
Concreting Quality Factors	0.659	1.517
Post-cast Quality Factors	0.491	2.038
Human Error Factors	0.576	1.736
Prefinish Quality Factors	0.818	1.222

Regression Analysis

The regression model was analyzed in SPSS software at a 95% confidence interval the model R-value was found to be 0.569 (positive). Given an R-value of 0.569, it fell into the category of a moderate correlation, as interpreted using Table 11. This suggested a reasonable linear relationship between the level of compliance and the quality factors being studied [49].

The positive R-value indicated a positive linear relationship between the level of compliance and the frequency of occurrence of quality control factors. Therefore, as the influence of quality factors increases, the low level of compliance increases and vice versa. The regressed model R^2 value was 0.324 (32.4%), and the adjusted R^2 value was 0.314 (31.4%). The R^2 change was 0.324 (32.4%).

According to [7], The R^2 metrics unmistakably indicate that the complete model matches the data. Therefore, the assessed quality factors explained about 32.4% variability of the level of compliance in quality and concrete waste management in the construction of buildings.

According to [45], R^2 values between 0.10 and 0.50 are acceptable in social science research. Therefore, the regressed model R2 value (0.324) was within the acceptable range. From the model summary, the F-statistic (5, 322) change value was 30.875 with a significant p-value at a 95% confidence interval ($p < 0.001$), as shown in Table 9.

From the ANOVA analysis, the Sum of Squares of Regression (SSR) was 11.526, and the Sum of Squares of Errors or residuals (SSE) was 24.042. The degrees of freedom values for the regression were 5 (dfregressor) and that of residual 322 (dfresidual). The Mean Square of Regression (MSR) was 2.305, and that of Errors (MSE) or residuals was 0.075. The F-statistic value was 30.875 and significant at a 95% confidence interval (p = <0.001), as shown in Table 9.

The p-value associated with the F-statistic suggested that the model is statistically significant at a 95% confidence interval. This provided significant evidence to reject the null hypothesis. The assumptions for ANOVA involve parametric data measures, normally distributed data, comparable variances among groups, and independence of subjects.

Nevertheless, the normality and variance assumptions can be overlooked without significant consequences when sample sizes are sufficiently large and an equal number of subjects in each group [48]. At least one predictor's coefficient is not equal to zero and significantly affects the dependent variable. Therefore, the assessed quality control factors greatly influence quality and concrete waste management compliance in the construction of buildings in Kenya.

The model intercept (constant) was found to be 0.870. The constant ensures the residuals don't have an overall bias [20]. The intercept was positive, indicating that without the influence of the quality factors, the predicted effect on the level of compliance has a baseline value that is either to be increased or decreased by the predictor variables.

Post-cast quality factors had the highest coefficient value (0.383), followed by prefinish quality factors (0.170) and then formwork quality factors (0.094). Concreting quality factors (0.041) followed and human error factors (0.009).

The constant, post-cast quality factors, pre-finish quality factors and formwork quality factors coefficients were significant at a 95% confidence interval as their p-values were <0.001, <0.001, 0.003 and 0.009, respectively. The p-values for precast quality factors (0.419) and human error factors (0.876) were insignificant at a 95% confidence interval. The standardized coefficients for the independent variables were all positive, as shown in Table 10.

According to [16], coefficients close to zero in logistic regression may suggest that the predictor variable lacks significant predictive value, as it predicts a nearly constant number. Such coefficients may indicate an essentially null response even if statistically significant or part of the Akaike best family of parameters. However, the significance of coefficients near zero can vary depending on the units of measurement for both the independent and dependent variables.

The regression model hence resulted as follows using the standardized coefficients;

$$\mathrm{Y} = 0.87 + 0.383Q_{pc} + 0.170Q_{pf} + 0.094Q_{f} + 0.041Q_{c} + 0.009Q_{h}$$

Where, 0.87 is the intercept, Q_{pc} is post-cast quality factors, Q_{pf} is prefinish quality factors, Q_f is formwork quality factors, Q_c is concreting quality factors, Q_h is human error factors, and Y is the level of compliance of quality control of concrete and concrete waste management.

The normality was checked by observing the Normal distribution plots and histograms for standardized and unstandardized residuals. The standardized residuals were compared with normal distribution represented by straight diagonal lines, as shown in Figures 8 and 9. Residual analysis was performed to check the model's validity by evaluating the following assumptions.

According to [6], before interpreting ANOVA results, it is advisable to check the main assumption that the residuals follow a normal distribution. A commonly used method for evaluating the normality of residuals is through a Q-Q plot, where the quantiles of the observed residuals are compared with the expected quantiles from a standard normal distribution.

The linearity and the normality assumptions are essential to meet multiple regression analysis requirements and, thus, should be fulfilled to ensure that the model represents the population's natural system [17]. This guarantees that the independent variables' prediction of the dependent variable is not exaggerated.

The linearity assumption can be confirmed in conjunction with the independence of the residuals, referred to as homoscedasticity. The scatter plot depicted that the residuals were independent as the pattern was random. Figure 10 shows the linearity of the dependent variable and the predictor residuals at a 95% confidence interval.

According to [32], the violation of homogeneity of variance is crucial, and it affects the output from the routine ANOVA technique. R^2 value from the analysis explained the variation of about 32.4% in the dependent variable because of the independent variables in the model. The F-statistic predicted the model fitness of regression as the significance level at 95% confidence level was statistically significant.

The critical F-statistic from the probability F-distribution tables was 2.21(5, 322) at a 0.05 significance level, which was less than the F-statistic value of 30.875(5, 322) with a statistically significant p-value of <0.001. This provided sufficient statistical evidence to reject the null hypothesis [44].

Therefore, the influential factors evaluated significantly affect the level of compliance. The coefficients and constant values βi and βo indicated the magnitude with which one unit change in the independent variable would change the dependent variable [6]. Post-cast quality factors were the most significant, followed by prefinish and formwork quality factors. The three factors had coefficients that were statistically significant at a 95% confidence interval, indicating that they had the most significant magnitude in the change of the compliance level (32.4%) compared to concreting factors and human error factors, whose coefficients were statistically insignificant.

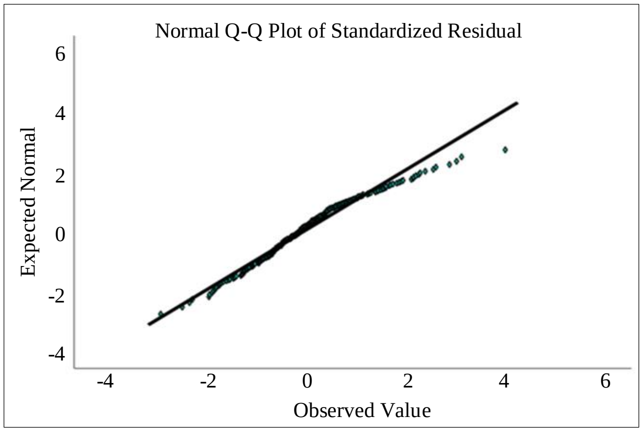

Fig. 5 Normality fit of the regression standardized residuals

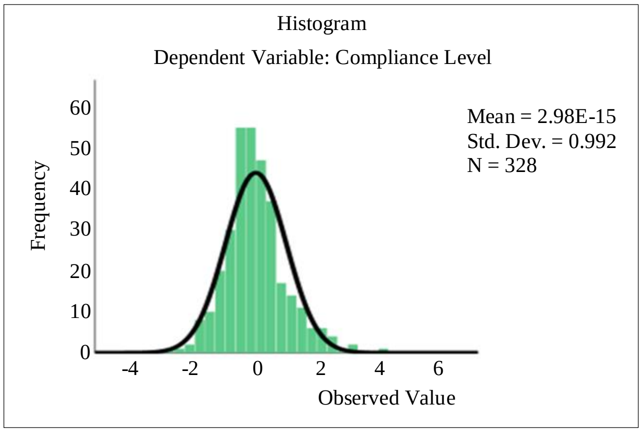

Fig. 6 Histogram forming a bell shape depicting a normal distribution of residuals to ascertain the basic requirements for a regression model

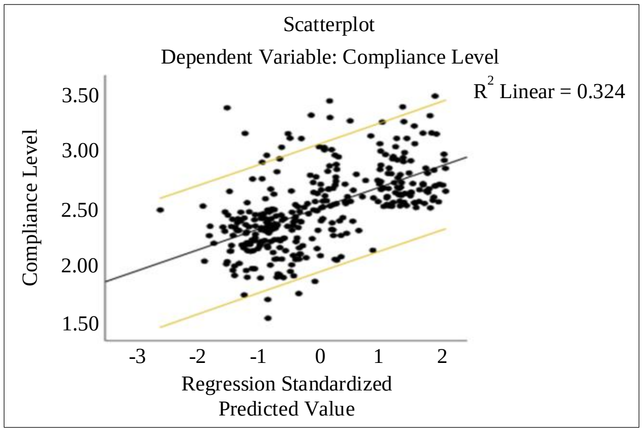

Fig. 7 A scatterplot showing the random distribution of observations with a regression best-of-fit line significant at a 95% confidence interval

Table 5. Ranking of quality influential factors in five categories with their Significance Potential Values (SPVs) that depict their criticality as quality control-related causes leading to the generation of concrete waste

Factors	Mean	Frequency Index	Significance Potential Value (SPV)	Rank	Potential Influence Level
Formwork Quality Factors					
Poor formwork stripping	4.12	0.824	83%	7	High
Formwork panels overuse	4.10	0.820	82%	8	High
Formwork misalignment defects	3.94	0.788	79%	14	High
Formwork early removal before concrete gains sufficient strength	3.87	0.774	78%	17	High
Formwork deflection defects	3.86	0.772	77%	20	High
Formwork installation complexity	3.81	0.762	76%	26	High
Formwork instability during casting	3.76	0.752	75%	27	High
Formwork limited adjustments	3.66	0.732	73%	32	High
Formwork shape's complexity, barring proper installation	3.64	0.728	73%	33	High
Formwork modification defects	3.62	0.724	72%	35	High
Formwork inaccessibility during casting	3.6	0.72	72%	36	High
Formwork incompleteness creates gaps	3.59	0.718	72%	37	High
Formwork failure during casting	3.53	0.706	71%	41	High
Poor formwork oil application	3.45	0.690	69%	45	Medium
Average			**75%**		**High**
Concreting Quality Factors					
Concrete segregation during casting	4.02	0.804	81%	9	High
Poor vibration of concrete during casting	4.01	0.802	80%	10	High
Excessive concrete shrinkage	3.90	0.780	78%	15	High
Concrete contamination in mixing and when pouring	3.83	0.766	77%	24	High
Excessive concrete bleeding	3.81	0.762	76%	25	High
Poor concrete workability	3.75	0.750	75%	28	High
Fresh concrete pouring delays	3.74	0.748	75%	29	High
Premature setting of concrete before placement	3.64	0.728	73%	34	High
Average			**77%**		**High**
Post-Cast Quality Factors					
Concrete cracks	4.49	0.898	90%	1	High
Honeycombing	4.49	0.898	90%	2	High

Factors	Mean	Frequency Index	Significance Potential Value (SPV)	Rank	Potential Influence Level
Uneven concrete surfaces after casting	4.21	0.842	84%	3	High
Exposed reinforcement after formwork removal	3.97	0.794	80%	11	High
Concrete delamination due to poor bonding	3.95	0.79	79%	12	High
Poor concrete curing practices	3.94	0.788	79%	13	High
Concrete cold joints	3.87	0.774	78%	19	High
Blocked embedded service conduits and pipes	3.73	0.746	75%	30	High
Concrete strength failure	3.73	0.746	75%	31	High
Dimension deviation of cast members	3.55	0.710	71%	39	High
Average			**80%**		**High**
Human Error Factors					
Rejection of supplied ready-mix concrete	4.18	0.836	84%	4	High
Improper transportation of concrete to placement points	4.17	0.834	84%	5	High
Excessive concrete overspills during casting	3.86	0.772	77%	21	High
Casting on rain	3.85	0.77	77%	22	High
Faulty concrete mixing equipment	3.53	0.706	71%	42	High
Excess order or production of concrete	3.49	0.698	70%	44	Medium
Faulty concrete pouring equipment	3.35	0.670	67%	46	Medium
Poor workmanship in handling concrete	3.31	0.662	66%	47	Medium
Average			**75%**		**High**
Prefinish Quality Factors					
Reinforcement reinstatement	4.16	0.832	83%	6	High
Demolition of elements due to low target strength of concrete	3.89	0.778	78%	16	High
Repairing blocked or omitted MEPs	3.87	0.774	78%	18	High
Hacking to remould architectural elements during finishing work	3.83	0.766	77%	23	High
Removal of contaminated concrete	3.56	0.712	71%	38	High
Hacking to realign beams, slabs, walls and columns	3.55	0.710	71%	40	High
Frequent design changes on-site	3.52	0.704	71%	43	High
Average			**76%**		**High**

Table 6. Model statistics on the R, R2, and F-statistic values with a significant p-value at 95% confidence interval

Model	**R**	**R^2**	**Adjusted R^2**	**Standard Error of the Estimate**	**Change Statistics**				
					R^2 Change	F-stat Change	df1	df2	P-value F-stat Change
	0.569	0.324	0.314	0.27325	0.324	30.875	5	322	<0.001
Predictors: (Constant), Prefinish Quality Factors, Human Error Factors, Concreting Quality Factors, Formwork Quality Factors, Post-cast Quality Factors Dependent Variable: Level of Compliance df: degrees of freedom									

Table 7. The standardized constant and coefficients for distinguished quality factors treated as independent variables in the regression model depicting the magnitude of influence by the factors in affecting the level of compliance

	Unstandardized Coefficients		**Standardized Coefficients**	**T-statistic (1.645, CI 95%)**	**P-Values**
	B	Coefficients Standard Error	Beta		
Constant	0.870	0.136		6.404	<0.001
Formwork Quality Factors	0.047	0.028	0.094	1.698	0.009
Prefinish Quality Factors	0.096	0.032	0.170	3.013	0.003
Post-cast Quality Factors	0.249	0.042	0.383	5.852	<0.001
Human Error Factors	0.004	0.028	0.009	0.156	0.876
Concreting Quality Factors	0.019	0.024	0.041	0.808	0.419
Dependent Variable: Compliance Level					

Table 8. Spearman's rank order correlation of influential factors

Factors		**Compliance Level**	**Formwork Quality Factors**	**Concreting Quality Factors**	**Post-cast Quality Factors**	**Human Error Factors**	**Prefinish Quality Factors**
Compliance Level	ρ	1	0.357	0.453	0.602	0.429	0.307
	p-value		<0.001	<0.001	<0.001	<0.001	<0.001
Formwork Quality Factors	ρ	0.357	1	0.315	0.408	0.376	0.383
	p-value	<0.001		<0.001	<0.001	<0.001	<0.001
Concreting Quality Factors	ρ	0.453	0.315	1	0.543	0.512	0.215
	p-value	<0.001	<0.001		<0.001	<0.001	<0.001
Post-cast Quality Factors	ρ	0.602	0.408	0.543	1	0.636	0.349
	p-value	<0.001	<0.001	<0.001		<0.001	<0.001
Human Error Factors	ρ	0.429	0.376	0.512	0.636	1	0.224
	p-value	<0.001	<0.001	<0.001	<0.001		<0.001
Prefinish Quality Factors	ρ	0.307	0.383	0.215	0.349	0.224	1
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	

4. Conclusion

The ranking of the quality control-based factors based on their probable criticality in generating concrete waste determined from frequency index and significance potential influence revealed that re-instating reinforcement, concrete fractures, inadequate formwork stripping, and the rejection of ready-mix concrete are among the highly influential factors found at different categories. Among the evaluated factors, positive relationships were discovered. Although there were differences in the intensity of the link, post-cast quality parameters and human error factors have a substantial relationship.

The degree of compliance and the frequency of occurrence of quality control-based factors depicted a modest connection in the model. Of the fluctuation in the compliance level, the model described 32.4% of a significant variation at a 95% confidence interval. This indicated that quality control factors significantly influence quality control and concrete waste management compliance. Post-cast quality factors have the highest positive coefficient value, indicating a substantial impact on the level of compliance. Other significant contributors are prefinish quality factors and formwork quality factors.

Human error factors and concreting quality factors have non-significant coefficients. This indicates that the level of compliance is influenced negatively when the quality control checks related to casting, formwork and preparation for finishes are not well addressed. The building contractors, therefore, need to have a quality control plan pertaining to the identified critical factors of post-cast defects, prefinish preparations and formwork to minimize concrete waste generation and improve the level of quality control related to concrete.

The quality control techniques and practices evaluated in this study for compliance are meant to boost labour productivity by decreasing rework and fostering optimal resource utilization. Building construction sites demand a high level of concrete quality control and inspections to minimize product flaws, leading to demolitions and reworks and contributing to substantial waste generation. Nevertheless, the building contractors must comply with the set waste management regulations and lay in plan waste management practices on-site that advocate for waste prevention and reduction. From the study results,

Given the strong impact of post-cast quality factors, construction project managers should prioritize robust quality control measures during and after the casting phase. Additionally, building contractors should implement prefinish quality controls and develop stringent initiatives to ensure the formwork meets quality standards. Training programs and strict protocols should be introduced to minimize concrete handling, transportation, and pouring errors.

At the same time, regular assessments should be conducted to identify emerging issues and adaptation strategies accordingly. Furthermore, communication and collaboration between project stakeholders, including contractors, suppliers, and workers, should be enhanced to ensure a shared understanding of quality control requirements related to concrete before, during and after construction of buildings.

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