"Assessing Construction Material Quality for Enhanced Durability and Sustainable Urban Development in South Bangalore"

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1. INTRODUCTION

The quality of materials used in construction is paramount for ensuring the safety, durability, and sustainability of buildings. High-quality materials are essential for maintaining the structural integrity of a building, preventing issues like cracking, corrosion, and weakening of structural elements. This, in turn, ensures the safety of the occupants and reduces the risk of structural failures, partial or complete collapses, and damage during natural disasters. Moreover, high-quality materials contribute to the longevity of a building by withstanding environmental factors like weathering, temperature fluctuations, and chemical exposure. They also often have a longer lifespan, minimizing the need for frequent repairs and replacements, which translates to less waste generation and a reduced environmental impact associated with material production and transportation.

1.1 Dangers of Substandard Materials

Using substandard materials in construction can have severe consequences. This increases maintenance costs as frequent repairs and replacements become necessary, adding to the financial burden. Furthermore, substandard materials significantly reduce the overall lifespan of the building, making it vulnerable to safety hazards and posing risks to the occupants. Additionally, the use of substandard materials has environmental implications. The increased waste generation from frequent repairs and replacements, coupled with the need for new materials, contributes to environmental problems.

The quality of construction materials is not just a matter of aesthetics or cost; it is a fundamental factor that determines the safety, durability, and sustainability of buildings. Prioritizing quality and adhering to industry standards are crucial to prevent structural failures and ensure the long-term integrity of buildings. By using high-quality materials, we can create safer, more durable, and environmentally responsible structures for the benefit of present and future generations.

Given the alarming frequency of such incidents, it is imperative to address the root causes proactively. To this end, we are initiating a comprehensive material testing project focused on various construction sites in South Bangalore. This initiative aims to assess the quality of materials used, ensure adherence to safety standards, and prevent future structural failures. By identifying and rectifying potential hazards early, we strive to safeguard the lives of residents and uphold the integrity of our built environment.

2.0. LITERATURE REVIEW

2.1. Background

Research indicates that the use of poor quality construction materials significantly contributes to structural failures across India, resulting in devastating consequences such as loss of human lives and substantial financial burdens, with South India being particularly affected due to its rapid urbanization and construction boom. Incidents like the catastrophic 2014 Chennai Moulivakkam collapse, which claimed 61 lives, and the more recent 2024 Bengaluru Babusapalya collapse, where 8 people perished, appear strongly linked to the use of substandard materials, such as untested concrete or undersized steel rods, highlighting a recurring pattern of compromised construction practices. An unexpected yet critical detail emerges in these cases: unauthorized construction, such as the addition of extra floors beyond approved designs, often amplifies the risk of failure, as seen in both Chennai and Bengaluru, where regulatory violations compounded material deficiencies.

The evidence points to systemic issues, including lax enforcement of building codes and widespread cost-cutting measures by builders seeking to maximize profits, as primary drivers of these tragedies. Statistical data reinforces this grim reality, with an average of approximately 1,751 deaths annually from building collapses between 2018 and 2022, reflecting the persistent danger posed by such practices across the country. In South India, states like Tamil Nadu have been hit hard, with a staggering 437 deaths recorded in 2011 alone, underscoring the region's vulnerability and the urgent need for stricter oversight and quality control to prevent further loss of life and mitigate the economic toll on affected communities.

2.2 Incidents and Impact

Poor quality construction materials have caused significant structural failures in India, especially in South India. For example, the 2014 Chennai Moulivakkam building collapse killed 61 people, with investigations pointing to substandard materials and deviations from approved plans (Wikipedia). Similarly, in 2024, a Bengaluru building collapse in Babusapalya killed 8, attributed to thinner-than-required pillar rods and poor construction practices, with illegal additional floors adding complexity (India Today). These incidents highlight how such failures lead to tragic loss of life and impose financial burdens on families and communities.

The 2016 Hyderabad Nanakramguda collapse, killing 11, was primarily due to design flaws and unauthorized construction, but poor materials likely contributed (New Indian Express). For comparison, the 2013 Mumbai Mazgaon collapse, killing 61, was linked to inferior materials and shoddy work, showing a broader national issue (Hindustan Times).

2.3 Statistical Context

Research suggests building collapses due to poor quality materials contribute to a national average of 1,751 deaths annually from 2018 to 2022, with about 1,198 from residential buildings (News18). In 2011, Tamil Nadu reported 437 deaths, the highest in South India, underscoring regional vulnerability (Times of India).

2.4 Case Studies: Real-Life Incidents in South India and Beyond

Table 2.1: Few Building Collapse Incidents in India Due to Poor Quality Construction Materials

Incident	Date	Reason	Source
2014 Chennai Moulivakkam	June 28, 2014	Poor quality materials, design flaws	Wikipedia, The Hindu, IJRBSM PDF
2024 Bengaluru Babusapalya	October 22, 2024	Substandard materials, illegal construction	India Today, The Hindu
2016 Hyderabad Nanakramguda	December 8, 2016	Inadequate design, unauthorized construction	New Indian Express, The Hindu
2013 Mumbai Mazgaon	September 27, 2013	Inferior materials, shoddy work	Hindustan Times, Wikipedia

Several incidents illustrate the devastating impact of poor quality materials on structural stability:

- **2014 Chennai Moulivakkam Building Collapse** On June 28, 2014, an 11-storey under-construction apartment block in Moulivakkam, Chennai, collapsed, killing 61 people, mostly construction workers. Investigations revealed multiple factors, including the use of poor quality construction materials, deviations from approved plans, inadequate foundation, and improper structural design. A research paper highlighted that materials such as concrete, steel, and bricks were not properly tested, violating the National Building Code (IJRBSM PDF). The Justice R. Regupathy Commission recommended measures like insurance packages for builders, indicating systemic issues (The Hindu). This disaster exposed carelessness by builders, with legal proceedings noting the use of substandard materials (Wikipedia).

- **2024 Bengaluru Babusapalya Building Collapse** On October 22, 2024, a seven-storey under-construction building in Babusapalya, Bengaluru, collapsed, resulting in 8 deaths and 13 rescues. The cause was attributed to sub-standard materials, with pillar rods being 18-20 mm thick instead of the required 28-30 mm, and possible issues with concrete mix. Illegal construction, including unauthorized additional floors, was also a factor, adding an unexpected layer of complexity to the issue (India Today). The building was illegal and built on 'B' kharab land, with three notices from the Bruhat Bengaluru Mahanagara Palike (BBMP) ignored, highlighting regulatory failures (The Hindu).

- **2016 Hyderabad Nanakramguda Building Collapse** In Hyderabad, a seven-storey building collapsed on December 8, 2016, killing 11 people. A JNTU-H team found the collapse was due to weak supporting structure, inadequate design, and excessive load on columns and foundation, with the structure originally designed for G+3 but built as G+6, violating regulations (New Indian Express). While poor quality materials were not explicitly mentioned, the structural deficiencies suggest possible material issues, contributing to the failure (The Hindu). The owner, Satyanarayana Singh, was arrested for violations, indicating systemic issues in enforcement.

- **2013 Mumbai Mazgaon Building Collapse (Broader Context)**

On September 27, 2013, a five-storey BMC staff colony in Mazgaon, Mumbai, collapsed, killing 61 people. Investigations suggested shoddy work and inferior- quality raw materials, with construction during a cement shortage in 1980 leading to possible adulteration (Hindustan Times). The building, expected to last 60 years, collapsed after just over 30, highlighting material quality issues (Wikipedia). This incident, outside South India, provides a comparative perspective on national challenges.

These cases demonstrate how poor quality materials, combined with regulatory lapses and unauthorized construction, lead to catastrophic outcomes, affecting both human lives and financial stability.

2.5 Statistical Data and Analysis

Statistical data provides a broader perspective on the scale of the issue:

- According to News18, between 2018 and 2022, there were 8,756 deaths due to collapse of structures in India, averaging about 1,751 per year, with 5,988 deaths from residential buildings, averaging 1,198 per year.

- Earlier data from Scroll.in indicates an average of 2,658 deaths annually from all structural collapses, with 1,260 from buildings and houses, based on figures up to 2014, showing a slight decrease in recent years.

- In 2011, Tamil Nadu recorded 437 deaths from building collapses, the highest in South India and second nationally after Uttar Pradesh (461), according to Times of India, highlighting regional vulnerability.

- The highest fatalities in a decade were recorded in 2011 with 3,161 deaths, indicating a persistent problem, with states like Tamil Nadu and Andhra Pradesh reporting over 150 deaths yearly, often linked to illegal construction and lack of maintenance (Factly).

This data underscores the systemic nature of the problem, with poor quality materials being a recurring factor in many collapses, leading to both human and economic costs.

2.6 Causes and Contributing Factors

The issue is compounded by several factors:

- **Use of Substandard Materials**: Materials like cement, steel, and concrete often fail to meet Bureau of Indian Standards (BIS) requirements, with examples like thinner pillar rods in Bengaluru and untested materials in Chennai.
- **Cost-Cutting Practices**: Builders prioritize profit, using cheaper materials or reducing quantities, such as less cement in concrete, as seen in the Mumbai Mazgaon case.
- **Lack of Enforcement**: Lax enforcement of building codes allows substandard practices, with inspections often inadequate, as evidenced by ignored BBMP notices in Bengaluru.
- **Corruption**: Bribes and unethical practices lead to approval of unsafe buildings, a factor noted in the Chennai collapse investigations.
- **Unauthorized Construction**: Building beyond permitted plans, like adding extra floors, exacerbates failures, as seen in Hyderabad and Bengaluru, adding complexity to the issue.

A study suggests that 60% of construction failures are due to collapse of formwork and inadequate materials, with 18% linked to faulty formwork materials, highlighting professional integrity issues (Imanagerpublications).

2.7 Impact on finance and human lives

The financial and human costs resulting from structural failures due to poor quality construction materials in India are profound and far-reaching, reflecting both immediate tragedies and long-term socioeconomic consequences. On the human front, the loss of lives is staggering, with incidents like the 2014 Chennai Moulivakkam collapse claiming 61 victims, mostly construction workers, and the 2024 Bengaluru Babusapalya collapse taking 8 lives, each representing an irreplaceable loss that leaves families grappling with grief and instability. Beyond fatalities, numerous injuries further compound the toll, adding physical and emotional burdens to survivors and their loved ones, while the national annual death toll averaging 1,751 from building collapses between 2018 and 2022 serves as a stark reminder of the urgent need for systemic intervention to halt this preventable carnage.

Financially, the burden is equally significant, encompassing a wide range of expenses such as extensive rescue operations that deploy emergency services, medical treatment for the injured, compensation payouts to victims' families, and the costly process of demolishing unsafe remnants and rebuilding structures to safer standards. Legal proceedings also drain resources, as seen in the aftermath of the 2014 Chennai collapse, where the Justice R. Regupathy Commission recommended compulsory insurance packages for builders to offset future liabilities, a measure that underscores the added financial implications for the construction industry (The Hindu).

3.0 OBJECTIVES AND SCOPE OF WORK

The primary objective of this project is to conduct a thorough quantitative and qualitative assessment of the construction materials used in the South Bangalore region. This assessment will involve collecting material samples from various construction sites and subjecting them to standardized quality tests. The study aims to analyze materials such as cement, aggregates, bricks, and steel, ensuring that they meet the necessary quality standards for safe and sustainable construction practices. By conducting this assessment, the project will provide valuable insights into the current state of construction materials in the region, identifying potential deficiencies that may impact structural durability.

One of the key objectives of this study is the identification of construction sites, sample collection, and data gathering. This step is crucial as it ensures a diverse and representative selection of materials used in real-world construction projects. By systematically collecting samples from multiple locations, the study aims to provide a broad understanding of material quality across different construction projects in South Bangalore.

Following the sample collection, the next objective is the characterization of construction materials, including cement, aggregates, bricks, and steel. This characterization process will involve performing a series of quality tests to evaluate the materials' physical and chemical properties. For instance, the acid immersion test will be used to assess the quality of TMT (Thermo-Mechanically Treated) steel, while bricks and blocks will undergo dimensional adequacy tests, compressive strength tests, and water absorption tests. Similarly, cement and aggregates will be subjected to basic tests to determine their suitability for construction applications.

Another critical goal of the project is the comparison of test outcomes with relevant Indian Standard (IS) codes or existing literature. This comparison will help in identifying any deviations or non-compliance issues in locally used materials. By benchmarking the results against established standards, the study will highlight the extent to which construction materials in South Bangalore adhere to industry regulations and quality expectations.

The project will also focus on assessing the impact of poor-quality materials on safety and sustainability in construction. Using Life365 software, the study will analyze how substandard materials affect the long-term durability of structures. This assessment will provide insights into potential risks, such as reduced structural lifespan, increased maintenance costs, and safety hazards that arise due to inferior material quality.

Lastly, the study aims to recommend improvements to enhance adherence to quality standards in local construction practices. Based on the findings, the project will propose practical solutions to ensure better material selection, improved testing protocols, and stricter quality control measures. These recommendations will help in promoting sustainable and safer construction practices, ultimately contributing to the overall improvement of infrastructure quality in the region.

By achieving these objectives, the project aspires to provide valuable data and actionable insights that can support policymakers, construction professionals, and regulatory bodies in making informed decisions to enhance construction material standards in South Bangalore.

4.0 MATERIALS AND METHODOLOGY PLANNED

The methodology of this project is structured into several key stages, ensuring a comprehensive assessment of the quality of construction materials used in the South Bangalore region. Each stage is designed to systematically collect, analyze, and interpret data, leading to meaningful insights and recommendations.

4.1 Site Visit, Sample Collection, and Data Collection

The first step in the methodology involves the selection and visitation of construction sites across the South Bangalore region. During these visits, material samples such as cement, aggregates, bricks, and steel will be collected from local construction projects. This step is crucial in ensuring that the study incorporates a diverse range of materials from different sources, reflecting the overall quality of construction materials used in the region.

Additionally, a survey-based questionnaire will be used to gather data on site quality management practices. The survey will involve discussions with site engineers, contractors, and workers to understand their quality control processes, procurement strategies, and any challenges they face in maintaining material quality. This qualitative data will help in correlating material quality with site practices and management efficiency.

4.2 Testing of Steel and Compliance Check

To evaluate the quality of TMT (Thermo-Mechanically Treated) steel samples collected from various construction sites, an acid immersion test will be conducted. This test is a rapid method to assess the presence of impurities and determine the corrosion resistance of the steel, which is a critical factor in ensuring structural longevity.

Following the test, the results will be analyzed to determine compliance with Indian Standard (IS) codes or other relevant guidelines. If deviations are found, the study will highlight the implications of using substandard steel and its potential impact on structural integrity.

4.3 Brick and Cement Testing

The quality of bricks will be assessed through multiple tests, including:

- Compressive strength test to measure their load-bearing capacity.
- Water absorption test to determine their porosity and resistance to moisture-related damage.
- Dimensional adequacy check to ensure uniformity and adherence to construction standards.

For **cement samples**, tests will include:

- **Fineness test** to determine the particle size distribution and surface area, which affects the cement's hydration rate.
- **7-day compressive strength test** to assess the early strength development of cement, which is crucial for initial structural stability.

These tests will help in identifying any deficiencies in the brick and cement quality, ensuring that they meet the necessary strength and durability requirements.

4.4 Testing of Fine Aggregates

Fine aggregates, which are a key component in concrete and mortar, will undergo various tests to evaluate their suitability for construction use. These tests include:

- **Type identification and source determination** to understand the origin and nature of the aggregates.
- **Gradation analysis** to assess particle size distribution, ensuring appropriate mix proportions for optimal concrete performance.
- **Moisture absorption test** to determine the water retention capacity of the aggregates, which influences concrete workability and strength.

By performing these tests, the study will establish whether the fine aggregates used in construction projects comply with quality standards and contribute to durable structures.

Steel Testing

- **Acid Immersion and TMT Ring Test**: A cross-section of the TMT bar is etched with 1% nitric acid to reveal the microstructure. A uniform tempered martensite ring surrounding a ferrite-pearlite core indicates proper TMT processing, as referenced in IS 1786:2008. The test is qualitative, resulting in a pass or fail based on visual inspection.
- **Yield Strength Test:** The yield strength is measured to confirm the steel meets Fe500 grade requirements, requiring a minimum of 500 MPa per IS 1786:2008.

Steel is considered good quality if it passes the acid immersion test and has a yield strength of at least 500 MPa.

Cement Testing

- **Compressive Strength Tests:** Tests were conducted at 7 and 14 days to assess strength development, assuming Ordinary Portland Cement (OPC) 43 grade per IS 8112:2013. The minimum requirement at 7 days is 33 MPa, and at 14 days, an interpolated threshold of 35 MPa is used, based on typical strength development curves where 14-day strength is approximately 80-90% of the 28-day strength (43 MPa). Cement is deemed good quality if both thresholds are met.

Brick Testing

- **24-Hour Water Absorption Test**: Bricks are submerged in water for 24 hours to measure water absorption, with a maximum of 20% considered acceptable for high- quality bricks per IS 1077:1992. Hardness and impact tests were not quantified due to their qualitative nature and are assumed to correlate with water absorption results.
- **Hardness and Impact Tests:** These qualitative tests assess surface hardness and resistance to impact. For simplicity, bricks with water absorption ≤20% are assumed to pass both tests, while those exceeding 20% may fail, though data is not explicitly generated for these tests.

Sand Testing

- Sieve Analysis: The fineness modulus is calculated to determine particle size distribution, with a range of 2.2 to 3.2 considered suitable for concrete sand per IS 383:2016. Sand is classified as good quality if the fineness modulus falls within this range.

4.5 Safety and Sustainability Assessment

The project will assess the impact of substandard construction materials on safety and sustainability. The study will provide insights into potential safety risks, increased maintenance costs, and environmental impacts associated with low-quality construction practices.

4.6 Data Analysis and Reporting

Once all material characterization, compliance testing, and performance evaluations are completed, the data will be systematically analyzed to derive meaningful conclusions. This phase involves:

- Compiling and analyzing test data to identify trends, patterns, and areas of concern.
- Comparing results with Indian Standard (IS) codes or existing literature to assess compliance levels.
- Preparing a detailed report that outlines the methodology, key findings, and conclusions drawn from the study.
- Discussing the broader implications of the results, including their impact on construction quality, structural safety, and sustainability.
- Providing recommendations for improving material quality and ensuring stricter adherence to construction standards in local projects.

In cases where fabrication work is required, the project will include an engineering drawing with dimensions and a detailed design, ensuring that all proposed improvements or modifications are well-documented and feasible for implementation.

By following this structured methodology, the project will provide a comprehensive assessment of construction material quality in South Bangalore, offering valuable insights for improving industry standards and ensuring long-term structural safety and sustainability.

5.0 OUTCOMES OF THE PROJECT

This report presents the results of material quality testing conducted across 20 construction sites in South Bangalore as part of the project titled "Evaluating Construction Material Quality and Its Impact on Durability and Sustainability in South Bangalore." The materials tested include steel, cement, bricks, and sand, with specific tests performed to assess their compliance with Indian Standard (IS) codes.

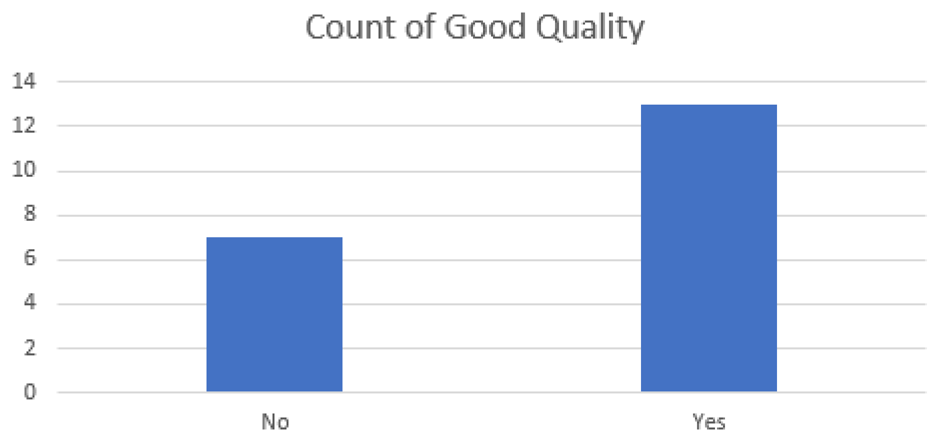
5.1 Steel Test Results

The following table presents the results for steel testing across the 20 sites.

Table 5.1: Steel Test Results

Site	Acid Immersion Test	Good Quality
1	Pass	Yes
2	Pass	Yes
3	Fail	No
4	Pass	Yes
5	Pass	No
6	Pass	Yes
7	Fail	No
8	Pass	Yes
9	Pass	Yes
10	Pass	Yes
11	Fail	No
12	Pass	Yes
13	Pass	Yes
14	Pass	No
15	Pass	Yes
16	Fail	No
17	Pass	Yes
18	Pass	Yes

19	Fail	No
20	Pass	Yes



13 out of 20 sites (65%) have steel that meets both the acid immersion test and Fe500 yield strength requirements. Sites 3, 7, 11, 16, and 19 failed the acid immersion test, indicating potential issues with TMT processing, which could lead to localized corrosion or inconsistent mechanical properties. Sites 5, 14, and 19 have yield strengths below 500 MPa, suggesting they do not meet Fe500 standards, which could compromise structural load- bearing capacity.

Durability: The quality of steel reinforcement is paramount for the longevity of reinforced concrete structures, as it bears tensile stresses and resists environmental degradation. Steel samples failing the acid immersion test (e.g., sites 3, 7, 11, 16, 19) exhibit non-uniform microstructure, lacking the characteristic tempered martensite ring required for Thermo- Mechanically Treated (TMT) bars per IS 1786:2008. This irregularity can lead to localized corrosion, particularly in humid or chloride-rich environments like South Bangalore, accelerating deterioration of the steel and surrounding concrete. Corrosion-induced cracking reduces the service life of structures, necessitating costly repairs or premature

demolition. Additionally, steel with low yield strength (e.g., sites 5, 14, 19, with values below 500 MPa) fails to meet Fe500 grade standards, compromising the load-bearing capacity of structural elements. This deficiency increases the risk of deformation or failure under design loads, posing safety hazards and further shortening the structure's lifespan. The combined effect of poor microstructure and inadequate strength at these sites undermines the durability of reinforced concrete, exposing structures to both environmental and mechanical vulnerabilities.

Sustainability: The sustainability implications of poor-quality steel are significant due to its influence on lifecycle costs and resource consumption. Steel that fails quality tests requires more frequent maintenance, repairs, or even replacement, each of which demands additional raw materials, energy, and labor. The production of steel is energy-intensive, contributing to high carbon emissions, and repeated interventions amplify this environmental burden. For instance, sites with substandard steel may necessitate retrofitting or reconstruction within a shorter timeframe, increasing the demand for steel and concrete, both of which have substantial ecological footprints. Conversely, high-quality steel, observed in 65% of sites (e.g., sites 1, 2, 4, 6, 8–10, 12, 13, 15, 17, 18, 20), supports durable structures that require minimal intervention over decades. This durability reduces the need for resource-intensive repairs, lowers lifecycle costs, and aligns with sustainable construction principles by conserving materials and energy. By ensuring compliance with IS 1786:2008, these sites contribute to environmentally responsible construction practices that prioritize long-term performance over short-term cost savings.

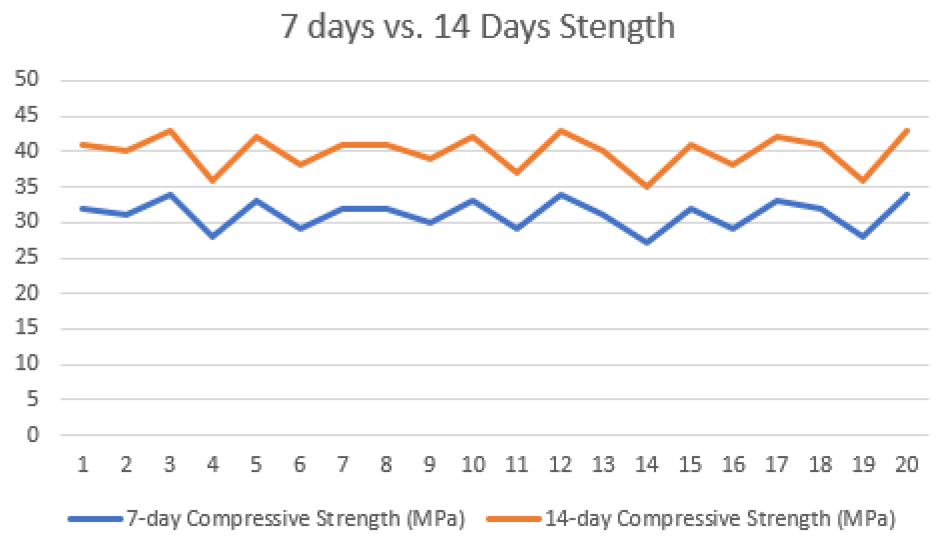
5.2 Cement Test Results

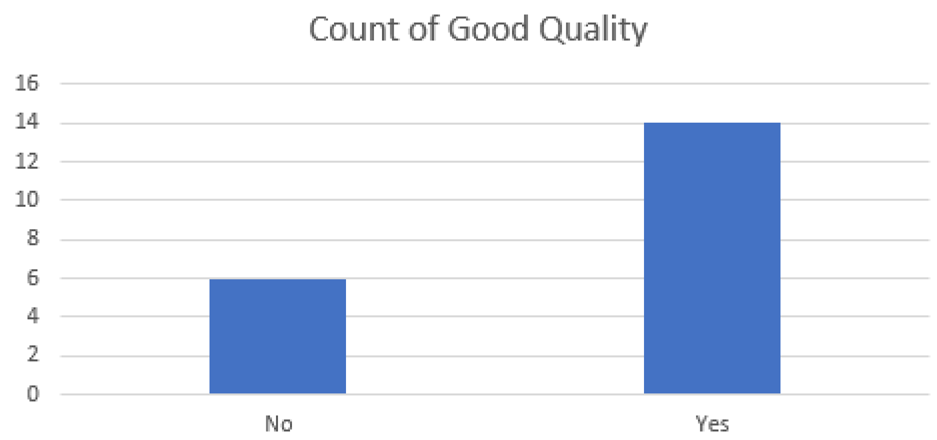
The compressive strength results for cement are shown below.

Table 5.2: Cement Test Results

Site	7-day Compressive Strength (MPa)	14-day Compressive Strength (MPa)	Good Quality
1	32	41	Yes
2	31	40	Yes
3	34	43	Yes
4	28	36	No
5	33	42	Yes
6	29	38	No
7	32	41	Yes
8	32	41	Yes
9	30	39	Yes
10	33	42	Yes
11	29	37	No
12	34	43	Yes
13	31	40	Yes
14	27	35	No
15	32	41	Yes
16	29	38	No
17	33	42	Yes
18	32	41	Yes

19	28	36	No
20	34	43	Yes





14 out of 20 sites (70%) have cement meeting the compressive strength criteria. Sites 4, 6,

11, 14, 16, and 19 have either 7-day strength below 30 MPa or 14-day strength below 35 MPa, indicating potential issues with cement quality that could result in weaker concrete structures.

Durability: Cement is the binding agent in concrete, and its compressive strength directly influences the structural integrity of buildings, roads, and other infrastructure. Cement samples with low compressive strength (e.g., sites 4, 6, 11, 14, 16, 19, with 7-day strengths below 33 MPa or 14-day strengths below 35 MPa) fail to meet the requirements for Ordinary Portland Cement (OPC) 43 grade per IS 8112:2013. Such cement produces weaker concrete that is more susceptible to cracking under compressive loads, thermal stresses, or environmental factors like moisture and temperature fluctuations prevalent in South Bangalore's climate. Cracked concrete allows water and aggressive agents (e.g., chlorides, sulfates) to penetrate, accelerating reinforcement corrosion and further degrading the structure. This deterioration compromises the concrete's ability to protect embedded steel, reducing the overall durability of the structure. Over time, these weaknesses may lead to spalling, loss of structural capacity, and the need for extensive repairs, significantly shortening the service life of the construction. In contrast, the 70% of sites with adequate compressive strength (e.g., sites 1–3, 5, 7–10, 12, 13, 15, 17, 18, 20) produce robust concrete capable of withstanding design loads and environmental exposure, ensuring long- term structural stability.

Sustainability: The environmental impact of cement quality is closely tied to its production process, which is one of the most energy-intensive and carbon-heavy in the construction industry. Substandard cement, as observed in 30% of sites, may require thicker concrete sections or additional repairs to compensate for its reduced strength, increasing the volume of cement used in construction and maintenance. Cement production accounts for approximately 8% of global CO_2 emissions, primarily due to clinker calcination and fuel combustion. Increased cement consumption at sites with poor-quality cement exacerbates these emissions, contributing to a larger carbon footprint and higher environmental costs. Moreover, frequent repairs or reconstruction due to weak concrete further amplify resource use, including aggregates, water, and energy, undermining sustainability goals. Conversely, the 70% of sites using high-quality cement produce durable concrete that minimizes the need for additional materials or interventions. This efficiency reduces the demand for cement production, lowers greenhouse gas emissions, and conserves natural resources like limestone and fossil fuels. By adhering to IS 8112:2013, these sites support sustainable construction by extending structure lifespans and reducing the environmental burden of maintenance.

5.3 Brick Test Results

The water absorption test results for bricks are presented below.

Table 5. 3: Brick Test Results for water absorption

Site	Water Absorption (%)	Good Quality
1	18	Yes
2	22	No
3	16	Yes
4	19	Yes
5	21	No
6	17	Yes
7	20	Yes
8	23	No
9	18	Yes
10	19	Yes
11	24	No
12	17	Yes

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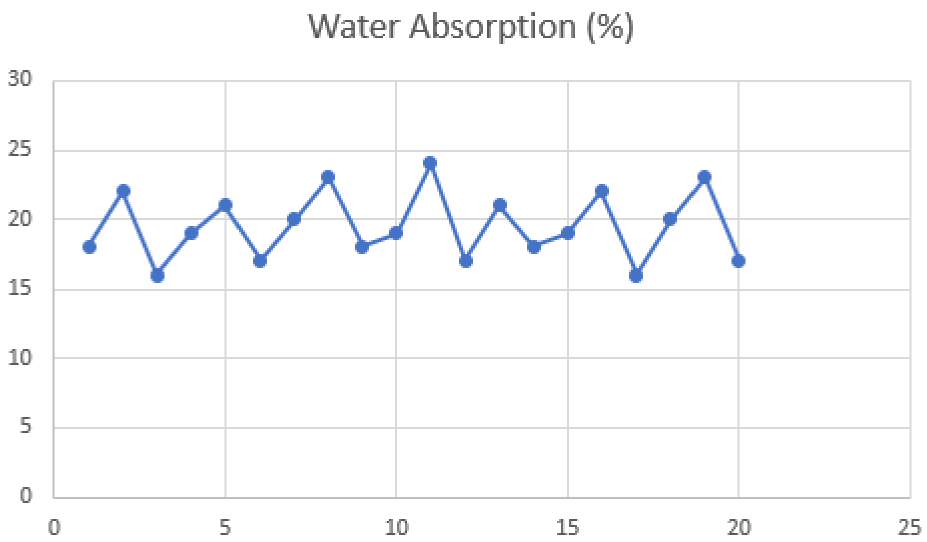
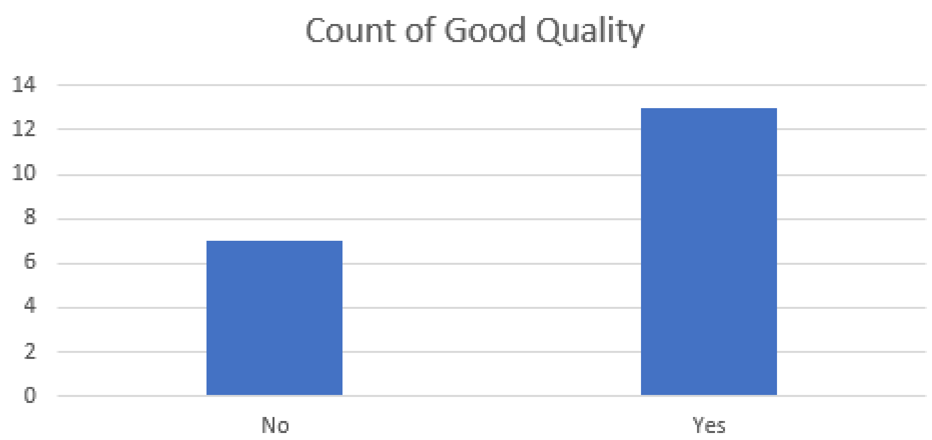
13	21	No
14	18	Yes
15	19	Yes
16	22	No
17	16	Yes
18	20	Yes
19	23	No
20	17	Yes





13 out of 20 sites (65%) have bricks with water absorption ≤20%, indicating good quality. Sites 2, 5, 8, 11, 13, 16, and 19 have higher absorption, which could lead to issues like dampness, reduced strength, and increased maintenance needs.

Durability: Bricks are a fundamental component of masonry structures, and their water absorption properties significantly affect their performance in walls, partitions, and other elements. Bricks with high water absorption (e.g., sites 2, 5, 8, 11, 13, 16, 19, with absorption >20%) exceed the threshold for high-quality bricks per IS 1077:1992, indicating excessive porosity. This porosity allows moisture to penetrate the brick, leading to dampness, which can weaken mortar joints and promote efflorescence—a crystalline salt deposit that damages aesthetics and structural integrity. In South Bangalore's humid climate, high-absorption bricks are particularly vulnerable to moisture-related issues, including mold growth and freeze-thaw damage in cooler seasons, both of which degrade the masonry over time. Prolonged exposure to moisture can also reduce the compressive strength of bricks, compromising the load-bearing capacity of walls and increasing the risk of cracking or collapse. In contrast, bricks at 65% of sites (e.g., sites 1, 3, 4, 6, 7, 9, 10, 12, 14, 15, 17, 18, 20) with water absorption ≤20% resist moisture ingress, maintaining their strength and structural integrity. These bricks contribute to durable masonry that withstands environmental stresses, ensuring long-lasting performance without frequent maintenance.

Sustainability: The sustainability of brick construction is influenced by the longevity of the material and the resources required for its maintenance or replacement. High-absorption bricks, found at 35% of sites, are prone to premature deterioration, necessitating repairs, replacements, or protective treatments such as waterproof coatings. These interventions consume additional materials (e.g., bricks, mortar, chemical sealants) and energy, increasing the environmental footprint of the structure. Brick production, particularly in traditional kilns, is energy-intensive and generates significant emissions, especially when low-quality bricks lead to higher replacement rates. Furthermore, the disposal of damaged bricks contributes to construction waste, straining landfill capacity and complicating waste management. In contrast, the 65% of sites using low-absorption bricks benefit from reduced maintenance needs, as these bricks maintain their integrity over time. This durability minimizes the demand for new bricks, conserves raw materials like clay and fuel, and reduces emissions associated with brick manufacturing. By complying with IS 1077:1992, these sites promote sustainable construction practices that prioritize resource efficiency and waste reduction, aligning with environmental goals for long-term urban development.

5.3 Sand Test Results

Since only FM values were provided without full sieve analysis data, grading zones were approximated using FM ranges commonly associated with each zone, based on civil engineering references:

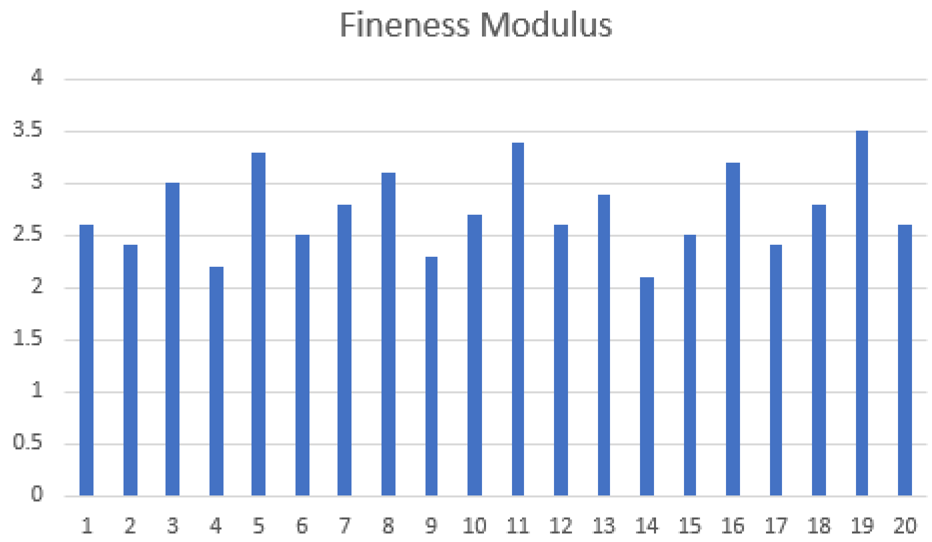
- **FM < 2.4**: Zone IV (very fine sand)
- **2.4 ≤ FM < 2.8**: Zone III (fine sand)
- **2.8 ≤ FM < 3.2**: Zone II (medium sand)
- **FM ≥ 3.2**: Zone I (coarse sand)

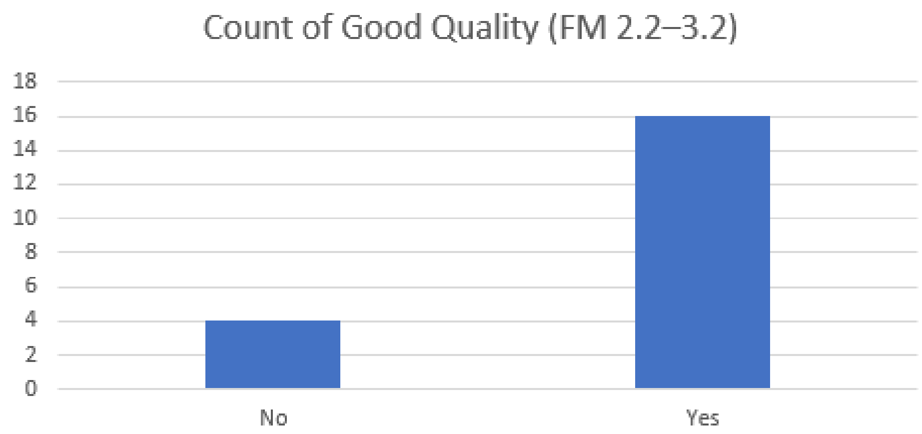
These ranges are approximations, as IS 383:2016 primarily uses percentage passing for zoning. However, FM provides a practical estimate, with higher FM indicating coarser sand. The FM values were previously assessed for quality, with 2.2–3.2 deemed suitable for concrete, aligning with Zones I, II, and III.

The FM values and corresponding grading zones for the 20 sites are presented below.

Table 5.4 : Sand Test Results with Grading Zones

Site	**Fineness Modulus**	**Grade**	**Good Quality (FM 2.2–3.2)**
1	2.6	Fine	Yes
2	2.4	Fine	Yes
3	3.0	Coarse	Yes
4	2.2	Fine	Yes
5	3.3	Coarse	No
6	2.5	Fine	Yes
7	2.8	Medium	Yes
8	3.1	Coarse	Yes
9	2.3	Fine	Yes
10	2.7	Medium	Yes
11	3.4	Coarse	No
12	2.6	Fine	Yes
13	2.9	Medium	Yes
14	2.1	Fine	No
15	2.5	Fine	Yes
16	3.2	Coarse	Yes
17	2.4	Fine	Yes
18	2.8	Medium	Yes
19	3.5	Coarse	No
20	2.6	Fine	Yes





Durability: Sand quality, assessed through fineness modulus (FM), directly affects the workability and strength of concrete, which are critical for structural durability. Sand with improper FM (e.g., sites 5, 11, 14, 19, with FM outside 2.2–3.2) fails to meet the requirements for concrete sand per IS 383:2016. At site 14 (FM 2.1, Zone IV), very fine sand may lead to excessive water demand, reducing concrete strength and increasing shrinkage, which causes cracking. Conversely, coarse sand at sites 5, 11, and 19 (FM ≥3.3, Zone I) can result in poor workability, leading to segregation or honeycombing in concrete, which weakens the structure and allows water ingress. These defects compromise the concrete's ability to protect embedded steel, accelerating corrosion and reducing the structure's lifespan. In South Bangalore's variable climate, such weaknesses exacerbate deterioration under moisture and temperature changes. In contrast, sand at 80% of sites (e.g., sites 1–4, 6–10, 12, 13, 15–18, 20) with FM between 2.2 and 3.2 (Zones II and III) ensures good workability and strength, producing dense, durable concrete that resists environmental degradation and maintains structural integrity over time.

Sustainability: The sustainability of sand use in concrete production hinges on its ability to optimize mix designs and minimize resource consumption. Unsuitable sand, as seen at 20% of sites, often requires higher cement content to achieve desired concrete properties, particularly for very fine sand (e.g., site 14). Increased cement use amplifies the environmental impact, as cement production is a major source of CO_2 emissions and consumes significant energy and raw materials. Coarse sand (e.g., sites 5, 11, 19) may necessitate additional processing or blending with finer aggregates, increasing energy use and costs. Poor-quality sand can also lead to weaker concrete, requiring repairs or reconstruction, which further escalates material and energy demands. In contrast, the 80% of sites with suitable sand (FM 2.2–3.2) enable efficient concrete mixes that reduce cement content while maintaining performance. This efficiency lowers the carbon footprint of concrete production and conserves natural resources like cement and aggregates. Additionally, durable concrete made with good-quality sand minimizes maintenance needs, reducing waste and aligning with sustainable construction goals. Compliance with IS 383:2016 at these sites supports environmentally responsible practices by optimizing resource use and extending structure lifespans.

5.4 Overall Construction Practice Analysis

The quality of construction materials across the 20 sites in South Bangalore reveals a mixed picture, with significant implications for structural safety, durability, and sustainability:

- **Steel**: With 65% compliance (13/20 sites meeting IS 1786:2008), issues with TMT processing (e.g., sites 3, 7, 11, 16, 19) and low yield strength (e.g., sites 5, 14, 19) at 35% of sites pose risks to structural safety. These deficiencies could lead to corrosion, reduced load capacity, and shorter service life, necessitating costly interventions.

- **Cement**: 70% compliance (14/20 sites meeting IS 8112:2013) indicates generally good cement quality, but the 30% of sites with low compressive strength (e.g., sites 4, 6, 11, 14, 16, 19) produce weaker concrete, increasing the likelihood of cracking and deterioration. This inconsistency undermines the reliability of concrete structures.

- **Bricks**: 65% compliance (13/20 sites meeting IS 1077:1992) highlights variability in brick manufacturing, with high water absorption at 35% of sites (e.g., sites 2, 5, 8, 11, 13, 16, 19) leading to moisture-related issues. These bricks compromise masonry durability and require additional maintenance.

- **Sand**: The highest compliance at 80% (16/20 sites meeting IS 383:2016) reflects consistent sand quality, but improper FM at 20% of sites (e.g., sites 5, 11, 14, 19) affects concrete performance, potentially increasing cement use and environmental impact.

Only 8 out of 20 sites (40%)—sites 1, 9, 10, 12, 15, 17, 18, and 20—consistently use high- quality materials across all four categories. This low proportion indicates that while some sites adhere to best practices, the overall construction practice in South Bangalore is inconsistent, with significant risks to structural integrity and sustainability. The variability in material quality suggests inadequate quality control, poor supplier selection, or lack of awareness about the long-term consequences of using substandard materials.

5.5 Recommendations

To address the identified issues and enhance the durability and sustainability of construction projects in South Bangalore, the following measures are proposed:

1. **Enhanced Quality Control**: Implement rigorous quality assurance protocols, including mandatory testing of all materials against relevant IS standards (IS 1786:2008, IS 8112:2013, IS 1077:1992, IS 383:2016) before use. Establish on-site testing facilities or partner with certified laboratories to ensure compliance.

2. **Supplier Vetting**: Source materials from reputable suppliers with a proven track record of delivering IS-compliant products. Require suppliers to provide test certificates and conduct periodic audits to verify material quality, reducing the risk of substandard supplies.

3. **Training and Awareness**: Educate site managers, engineers, and contractors on the critical role of material quality in achieving durable and sustainable structures. Conduct workshops highlighting the environmental and economic benefits of using high-quality materials, emphasizing lifecycle cost savings over initial cost reductions.

4. **Regular Audits**: Perform periodic audits of material quality and construction practices across all sites to identify and rectify issues early. Use audit findings to update quality control processes and inform supplier selection, ensuring continuous improvement in material standards.

5.6 Conclusion

The material quality testing across 20 construction sites in South Bangalore reveals a concerning level of inconsistency, particularly in steel and brick quality, with only 40% of sites (8/20) consistently using high-quality materials across all categories. Steel failing microstructure or strength tests, cement with inadequate compressive strength, bricks with high water absorption, and sand with improper fineness modulus pose significant risks to structural durability, increasing the likelihood of corrosion, cracking, and premature deterioration. These deficiencies also undermine sustainability by driving higher material consumption, energy use, and carbon emissions through repairs and replacements. While 65–80% of sites meet quality standards for individual materials, the lack of uniform compliance across all materials highlights the need for improved quality control, supplier vetting, and education. By adopting the recommended measures—enhanced testing, reliable sourcing, training, and audits—the project can achieve safer, longer-lasting, and more environmentally friendly structures, aligning with the goals of durable and sustainable construction in South Bangalore.

6. Questionnaire survey

What kind of structure is being constructed?

- ○ Frame
- ○ RCC
- ○ Other

What is the budget of the project?

- ○ <5cr
- ○ <10cr
- ○ 10cr to 50cr
- ○ >50cr

Name of the project

Your answer

Location

Your answer

What kind of construction is being done?

- ○ Residention
- ○ Commercial
- ○ Government
- ○ Other

How is the material testing done?

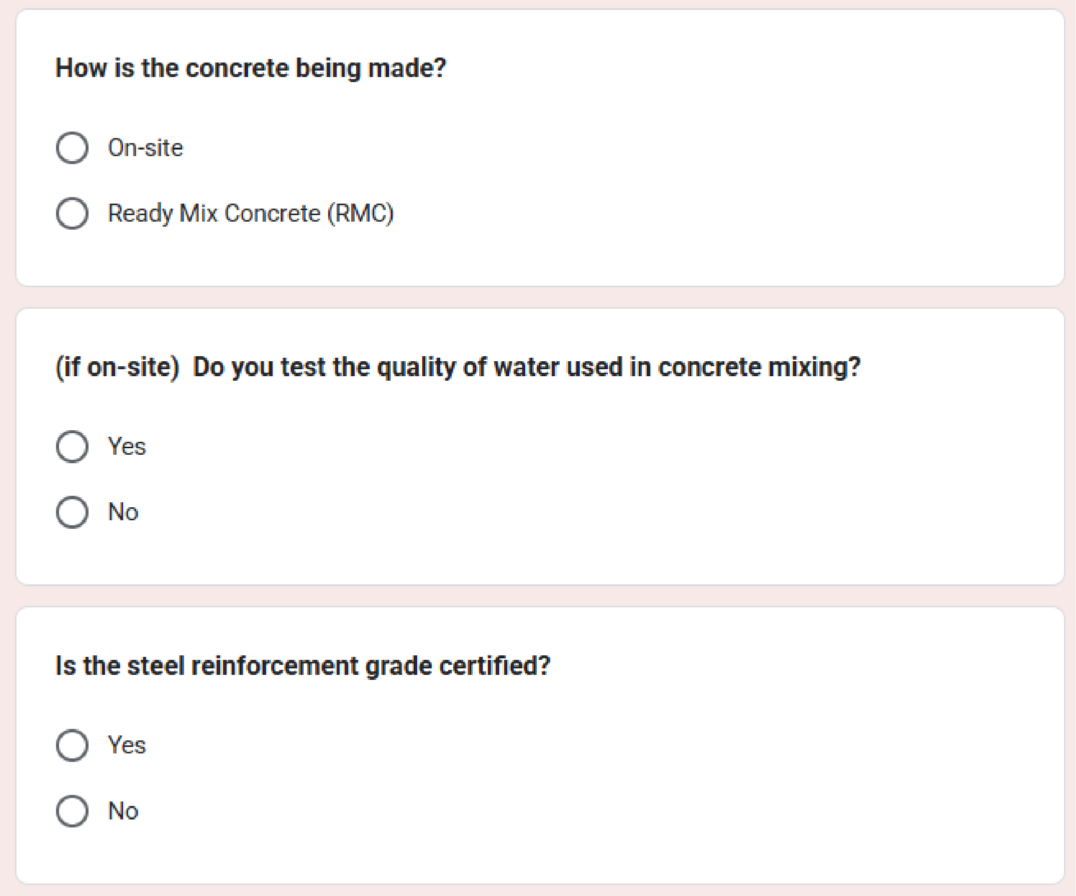
- ○ On-site
- ○ Through a 3rd party

What are the tests that are being done?

Your answer

What kind tests are being performed on the materials? (compressive strength test, tensile strength test, durability test, etc.)

Your answer



How is the concrete being made?

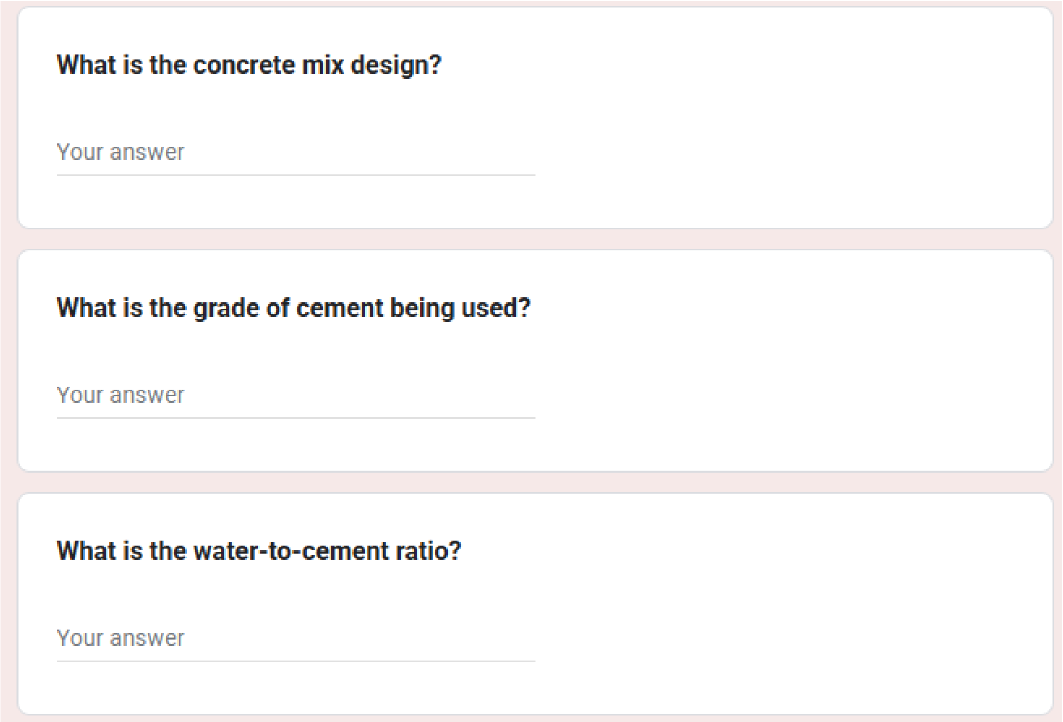
- On-site
- Ready Mix Concrete (RMC)

(if on-site) Do you test the quality of water used in concrete mixing?

- Yes
- No

Is the steel reinforcement grade certified?

- Yes
- No



What is the concrete mix design?

Your answer

What is the grade of cement being used?

Your answer

What is the water-to-cement ratio?

Your answer

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What are the sustainable materials being used?

- [ ] Bamboo
- [ ] Recycled concrete
- [ ] Reclaimed wood
- [ ] Hempcrete
- [ ] Recycled steel
- [ ] Other

What is the curing method being used? (Ponding, spraying, etc.)

Your answer

What kind of shuttering is being done?

- ○ Plywood shuttering
- ○ Metal shuttering
- ○ Other

Do you use branded cement or local cement?

- ○ Branded
- ○ Local

Is the cement stored in a dry, covered area?

- ○ Yes
- ○ No

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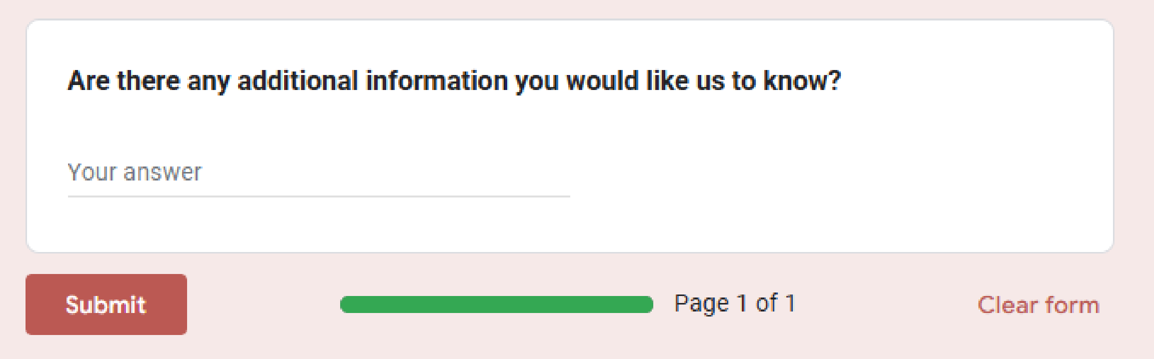
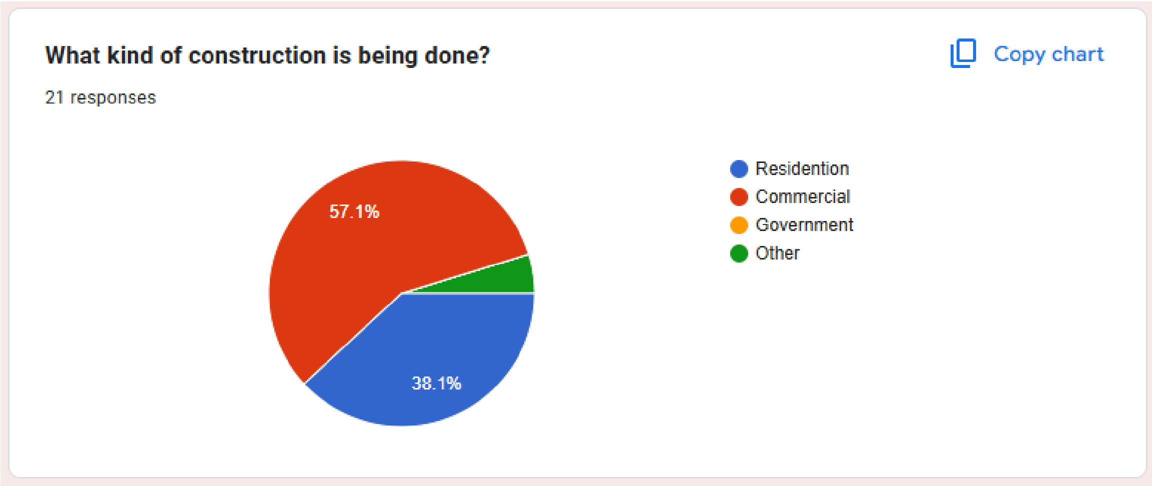
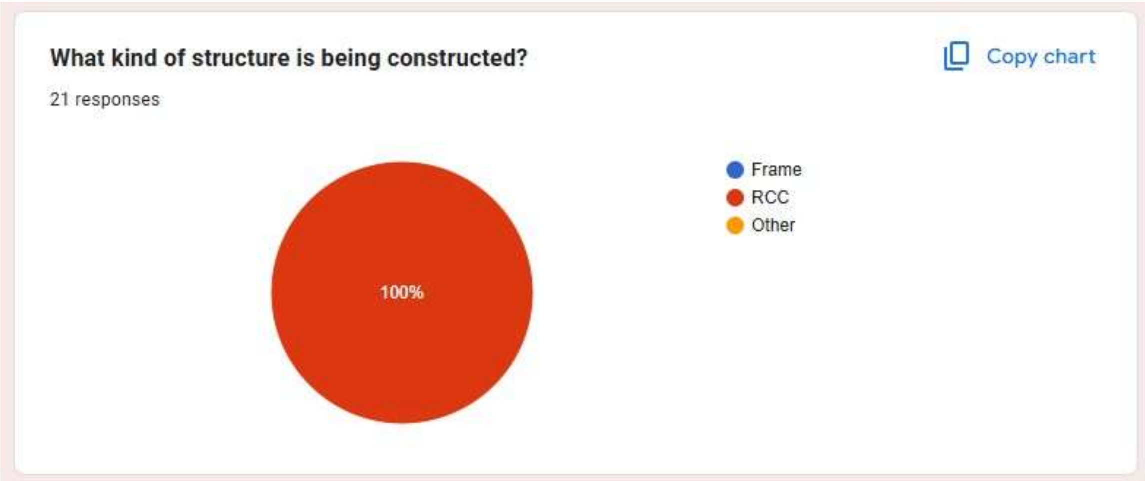
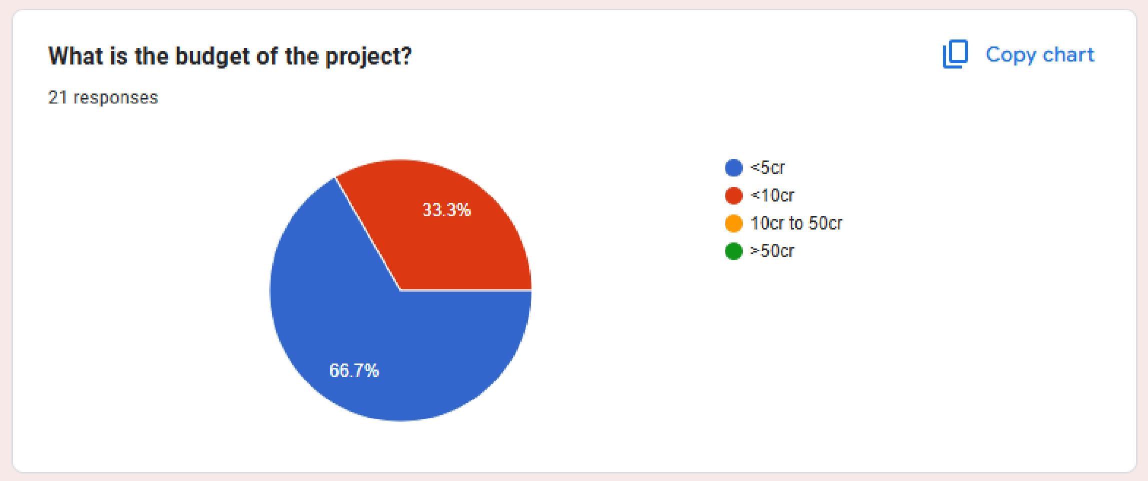
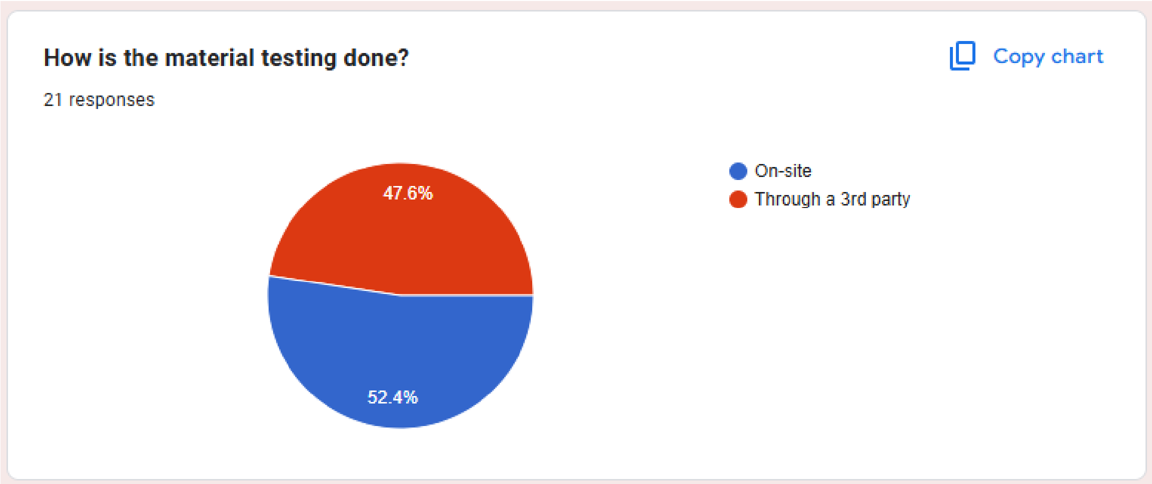


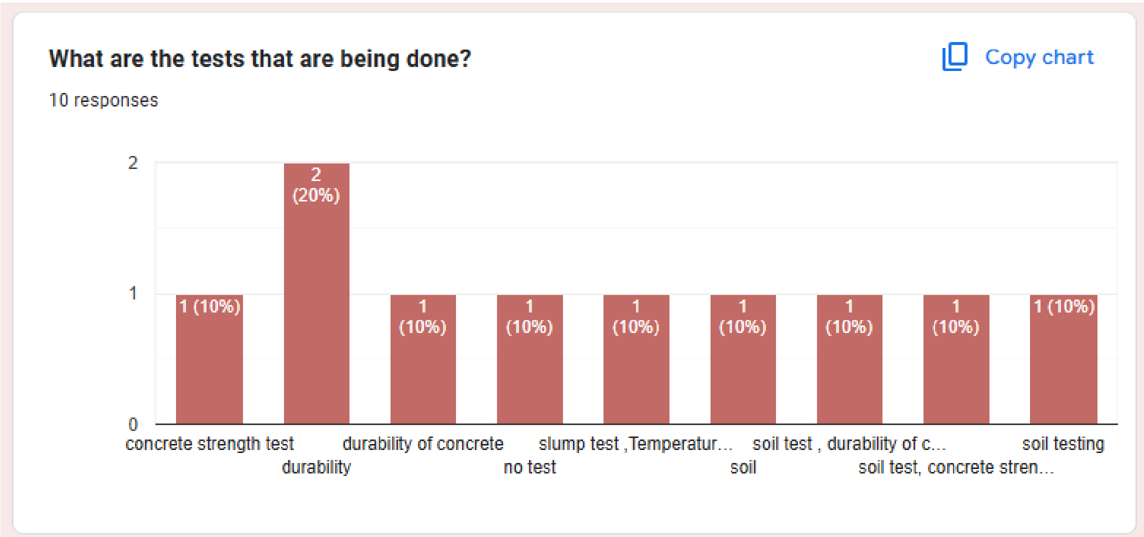
6.1 Survey results

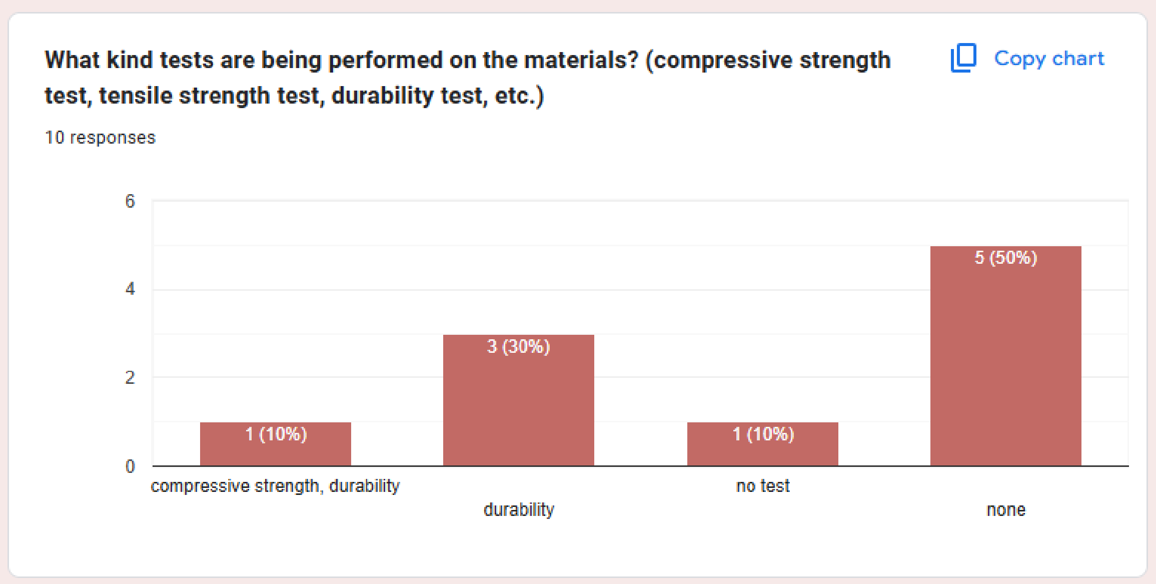


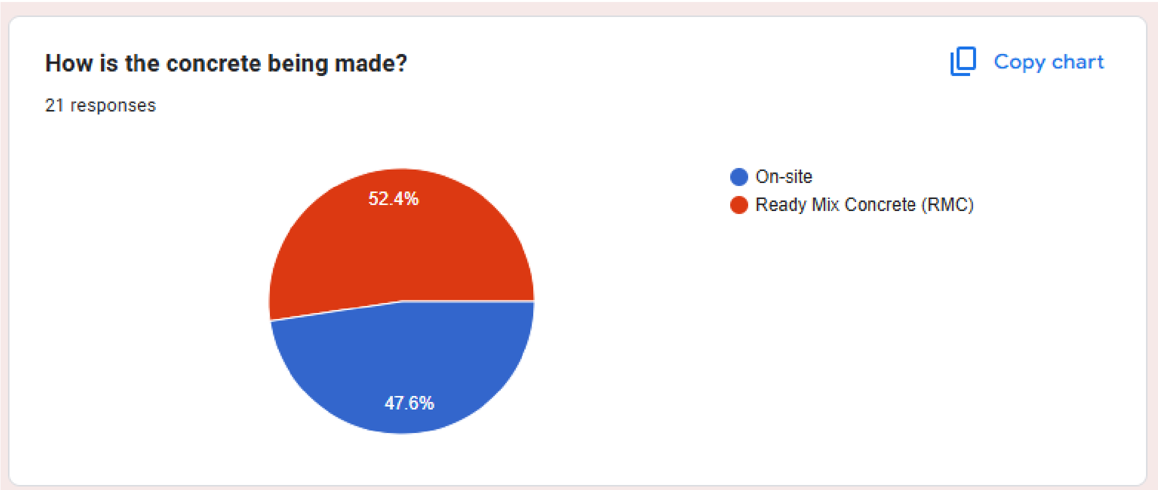


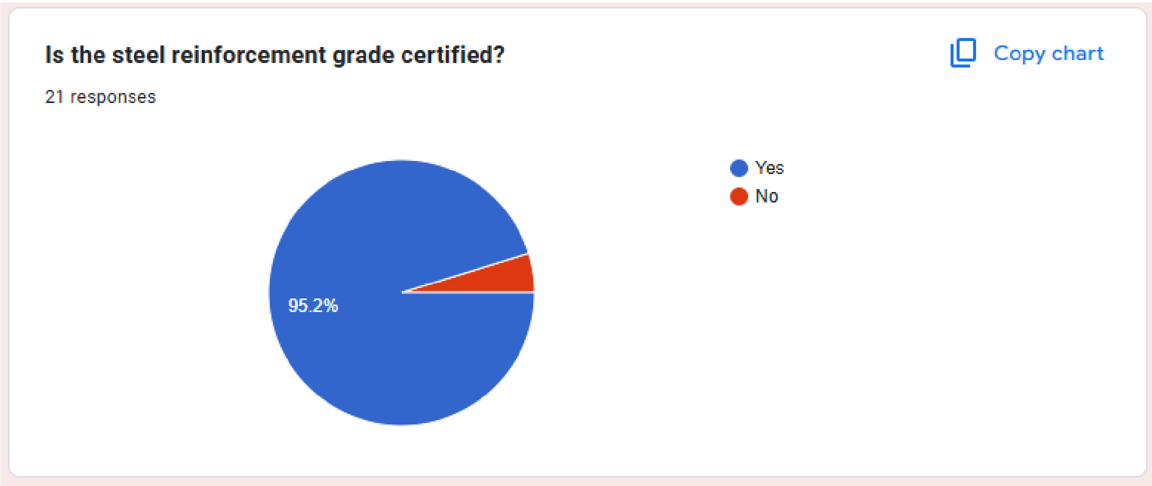

What is the budget of the project?
Copy chart
21 responses
33.3%
66.7%
<5cr
<10cr
10cr to 50cr
>50cr

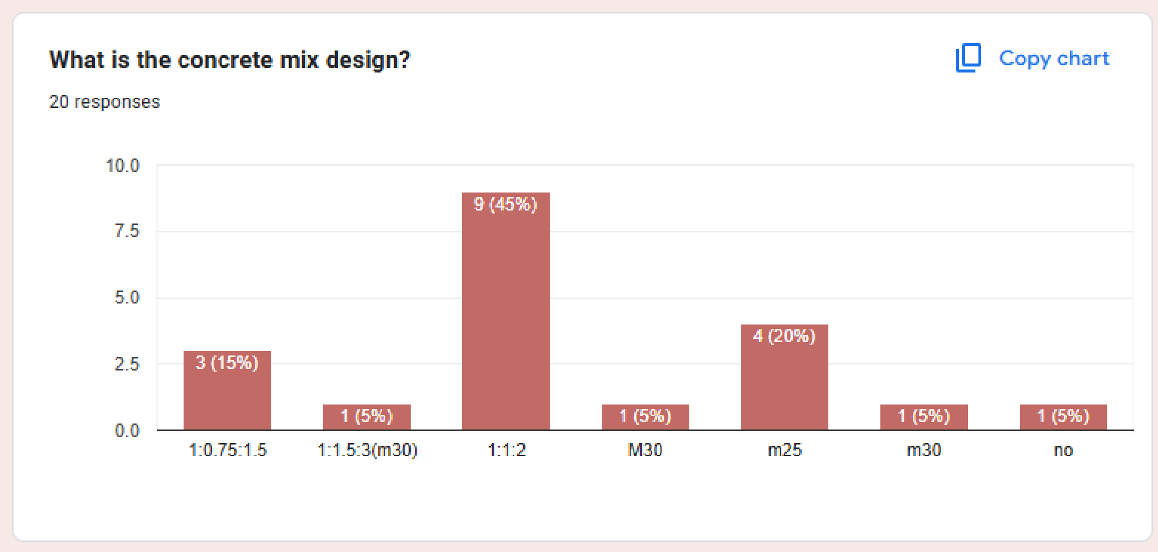

How is the material testing done?
Copy chart
21 responses
47.6%
52.4%
On-site
Through a 3rd party

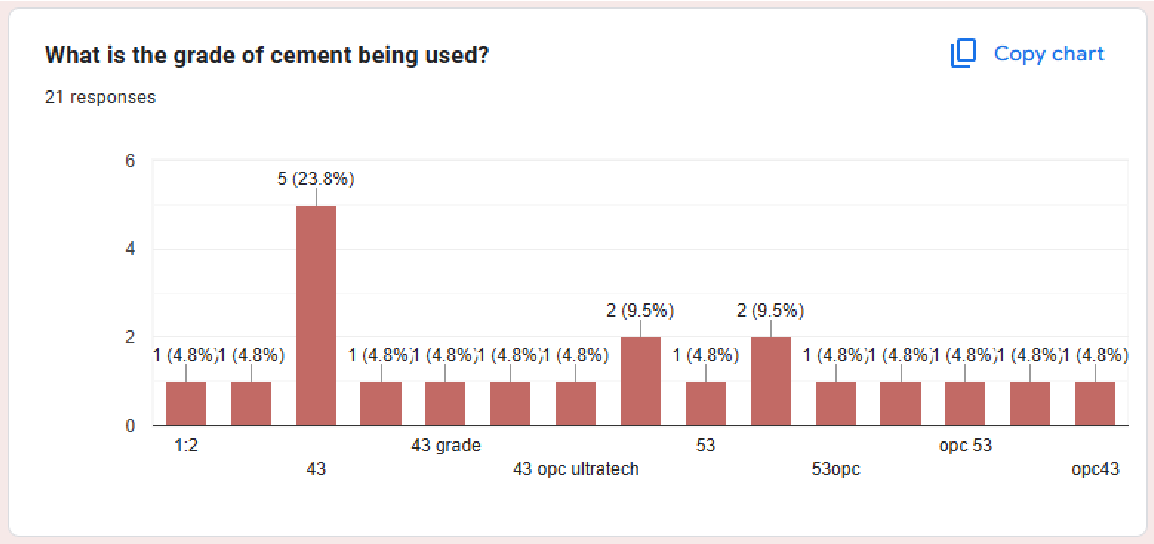

What are the tests that are being done?
Copy chart
10 responses
2
1
0
1 (10%)
2 (20%)
1 (10%)
1 (10%)
1 (10%)
1 (10%)
1 (10%)
1 (10%)
1 (10%)
concrete strength test
durability
durability of concrete
no test
slump test ,Temperatur...
soil
soil test , durability of c...
soil test, concrete stren...
soil testing

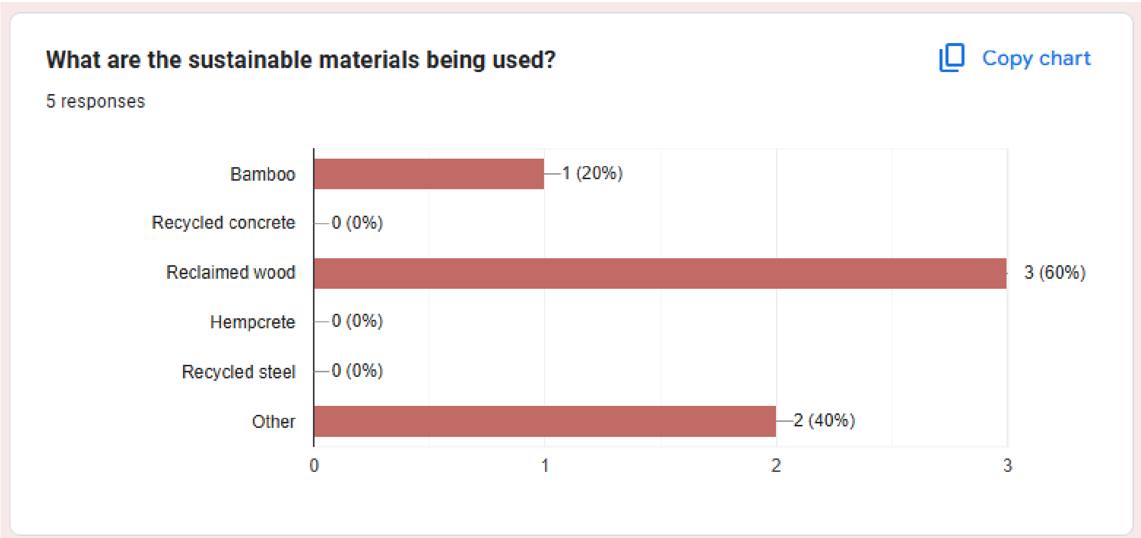

What kind tests are being performed on the materials? (compressive strength test, tensile strength test, durability test, etc.)
10 responses
Copy chart
6
4
2
0
1 (10%)
3 (30%)
1 (10%)
5 (50%)
compressive strength, durability
durability
no test
none

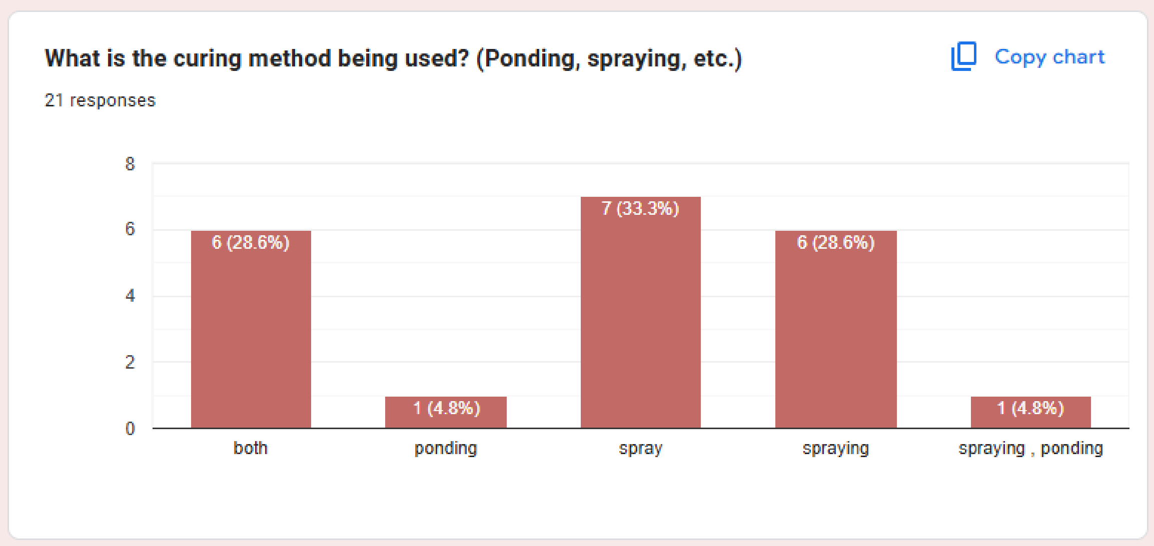

How is the concrete being made?
21 responses
Copy chart
On-site
Ready Mix Concrete (RMC)
52.4%
47.6%

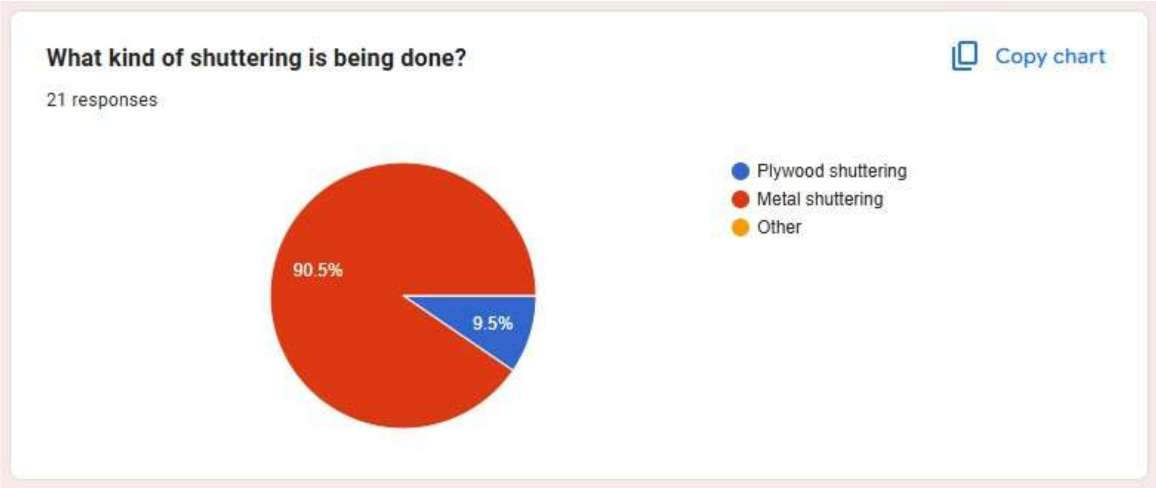

Is the steel reinforcement grade certified?
21 responses
Copy chart
Yes
No
95.2%

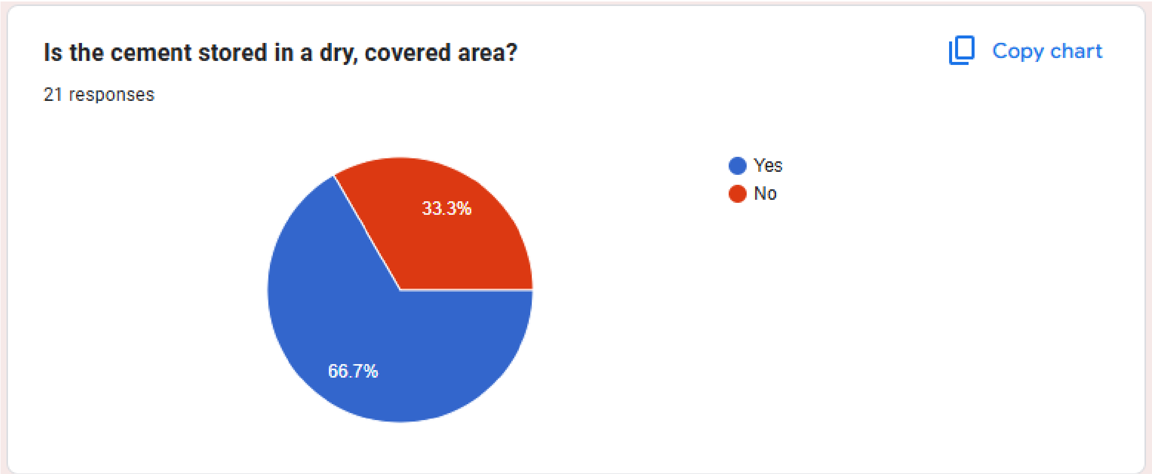

What is the concrete mix design?
Copy chart
20 responses
10.0
7.5
5.0
2.5
0.0
3 (15%)
1 (5%)
9 (45%)
1 (5%)
4 (20%)
1 (5%)
1 (5%)
1:0.75:1.5
1:1.5:3(m30)
1:1:2
M30
m25
m30
no


What is the grade of cement being used?
Copy chart
21 responses
6
4
2
0
5 (23.8%)
2 (9.5%)
2 (9.5%)
1 (4.8%)
1:2
43
43 grade
43 opc ultratech
53
53opc
opc 53
opc43


What are the sustainable materials being used?
Copy chart
5 responses
Bamboo
Recycled concrete
Reclaimed wood
Hempcrete
Recycled steel
Other
1 (20%)
0 (0%)
3 (60%)
0 (0%)
0 (0%)
2 (40%)
0
1
2
3


What is the curing method being used? (Ponding, spraying, etc.)
Copy chart
21 responses
8
6
4
2
0
6 (28.6%)
1 (4.8%)
7 (33.3%)
6 (28.6%)
1 (4.8%)
both
ponding
spray
spraying
spraying , ponding


What kind of shuttering is being done?
Copy chart
21 responses
90.5%
9.5%
Plywood shuttering
Metal shuttering
Other


Is the cement stored in a dry, covered area?
Copy chart
21 responses
33.3%
66.7%
Yes
No



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Sustainable Development Goals (SDGs)

Field	**Details**
Types of Project	Review & Research
Project Addresses	Sustainability, Safety, And Ethics
Number of SDGs Addressed	4 SDGs addressed (9, 11, 12, and 13)