Assessment on Materials Quality Control Implementation of Building Construction Projects and Workmanship: A Case Study of Ambo University

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Assessment on Materials Quality Control Implementation of Building Construction Projects and Workmanship: A Case Study of Ambo University

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Abstract— **Quality of material issues have been a significant source of concern since the dawn of recorded history. Building materials are essential and should be performed according to standard specifications because they cover around 60% of the project cost. Prior to project construction, specific codes, standards, and specifications should be available. Using all required materials does not guarantee a sound building appearance or function. Even with suitable materials, workmanship, and supervision, unexpected output can affect a building. Quality workmanship is a comprehensive approach to bolstering building durability, serviceability, and safety. The study evaluated Ambo University's building construction materials and quality. Convenience and quota sampling techniques were collected from all contractors and consultants involved in building construction via questionnaires and interviews. A comprehensive literature review identified 15 major factors affecting building construction materials quality and workmanship, and respondents ranked them in the order of importance. Defects in existing buildings and ongoing projects had observed due to non-compliance with construction materials and workmanship based on specifications and standards. The results indicated that Ambo University building has no defect-free structure, including the degree and type of defects vary. A 94% of the studied buildings had moisture leakage, plastering defects, paint peeling, and cracks. Hence, the consultants and Ambo University project representatives should adhere with the standard specifications, and must exercise their profession according to the ethical code of conduct. All of these, it will play a vital role in the success of construction projects.**

Keywords—**Building Projects, Contract Documents, Materials, Workmanship, Quality Control Implementation, Specifications, Standards.**

I. Introduction

Quality control is the process of comparing actual performance to goals and determining corrective action. It is the process that monitors specific project results to ensure they meet standards and identifies ways to improve performance. It is an issue of attention in construction work due to problems associated with the project methods and techniques [1]. To meet the required standards, there should be clear drawings and specifications.

Building construction uses resources such as labor, materials, and machinery. Building materials are vital in today's technologically advanced world. Their primary use is in construction, but they are essential in all fields of engineering. Also, the building materials industry is vital to our national economy because its output determines the speed and quality of construction. Material surpluses may occur due to engineering, procurement, and field material management deficiencies [2-4, 18].

Approximately 90% of project failures are due to poor communication, inadequate checks and controls, and a lack of technical expertise. Examining the defects within the project site improves the work quality and reduces costs. Many projects suffer from poor maintenance and inefficient material usage. Most defects and failures in building structures are caused by inferior quality. Out of all structures, public buildings are the most prone to substandard construction. Incorrect compaction techniques, reinforcement issues, and other failures occur due to oversight by the concerned organization [5, 6, 19].

Quality control of construction materials is now an important issue in construction projects. The management system and application ensure the right quality and quantity of materials and installed equipment are specified promptly, obtained at a reasonable cost, and available when needed. It is widely acknowledged that construction material management involves the integrated coordination of material takeoff, purchase, and disposal. Incorrect management of these functions can lead to material shortages, surpluses, and cash flow issues. Construction material shortages cause costly labor delays. Weakness, durability, and appearance are the results of poor material quality and workmanship [7].

Implementation means putting into practice a methodology, plan, or design. An action plan that follows an order or structure to achieve a goal [8, 9]. Using all required materials does not guarantee a sound building appearance or function. Even with suitable materials, workmanship, and supervision, the unexpected can affect a building. It may occur years after construction. So regular inspection and maintenance will be required. Materials account for roughly 60% of project costs. Because materials account for a large portion of the project's cost, improving material management and preventing problems will improve the overall building construction [2, 10].

Various studies showed that most Ethiopian construction companies lack quality control programs, resulting in substandard projects. Universities are rapidly expanding in Ethiopia. They have poor-quality buildings and even under-construction projects. Ambo University is one of those universities. The research helped identify issues with building projects and their quality to improve building projects at Ambo University. Quality control of construction materials is now an essential issue in the study area and entire Ethiopia.

Poor material quality and workmanship lead to loss of money, time, strength, durability, and appearance [7, 11, 19]. Ambo University's buildings are in poor condition, and the university loses money on maintenance. Some buildings' functionality is also lacking. Ambo University has four campuses: Main Campus, Awaro Campus, Guder Campus, and Woliso Campus. Many buildings with various functions such as administration, classrooms, dormitories, libraries, teaching, and referral hospitals have been built or are about to complete on these campuses. Many building defects are visible on buildings constructed with inferior materials and workmanship. It evaluated selected Ambo University buildings' materials quality control and workmanship and the factors affecting materials quality.

The study focused on doing the following objectives: (1) to identify factors affecting building construction materials quality and building workmanship in Ambo University building projects; (2) to assess the status of Ambo University buildings based on their construction materials and workmanship by using observations, desk studies, and interviews; and, (3) to suggest possible mitigations for the practical problems and recommend basic requirements for the present and future building project works.

II. Research Methodology

A. Study Area

The study was conducted at Ambo University Buildings, with campuses as follows: Main Campus, Awaro Campus, Guder Campus, and Woliso Campus, which are located in Ambo, Ambo, Guder, and Woliso towns, respectively.

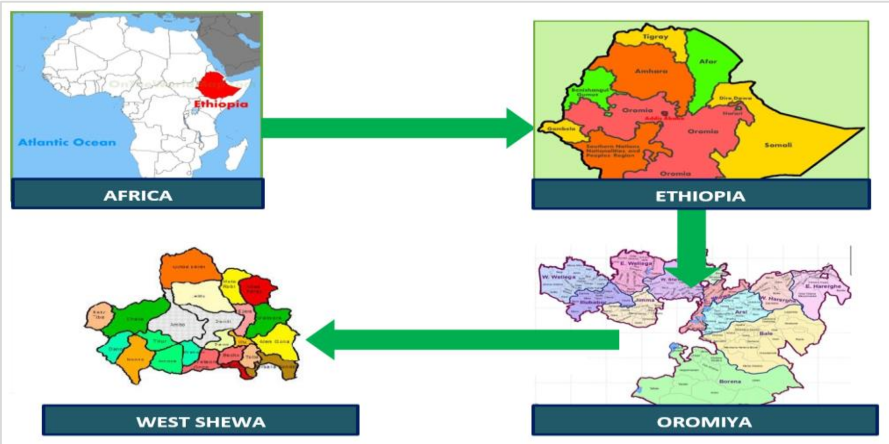

Fig. 1 Location map (Source: Google map 2021)

B. Research Design

Following a literature review, major factors affecting materials quality and workmanship were identified. Buildings at Ambo University are classified based on their functions: Administration, dormitories, libraries, Teaching and Referral hospitals, Others (Laboratories, Offices, Clinics, etc.). The study evaluated the materials quality control and workmanship of selected G+2 and higher university buildings. Existing and planned G+2 buildings were visually inspected in details. Restrictions on the use of contract documents are not imposed.

A comprehensive review of previously published works, internet data, and other related files was organized to assess the building materials quality control implementation and workmanship on the selected buildings. Questionnaires and interview instruments are used to collect data. Across Ambo University's four campuses, convenience sampling and quota sampling were used to determine the required sample size and type. Likewise, the researcher used a quantitative approach to analyze the questionnaire data.

C. The population of the Study and Sample Size Selection

As a case study, the study utilized respondents and buildings G+2 and above in Ambo University. The sample size was chosen using convenience sampling and quota sampling techniques based on accessibility and specific characteristics. All Ambo University contractors and consultants had been selected based on accessibility. In the particular character of building height, G+2 and above buildings were chosen because they accounted for over 90% of all buildings. Only 26 contractors and 3 consultants were available to respond during the research period. Buildings G+2 and above were studied for material quality control and workmanship. Nine others (mixed purpose buildings) were investigated, along with 30 dormitories. The samples were instrumental in gathering all necessary data.

TABLE I

GENERAL PROFILE OF THE ASSESSED PROJECTS

No.	Project Name	Height	No. of Bldgs.	Status	Location
EXISTING BUILDINGS					
1	Dormitories	≥G+2	30	Completed	All Campuses
2	Classrooms and Seminar	≥G+2	16	Completed	All Campuses
3	Libraries	G+3	5	Completed	All Campuses
4	Laboratories	G+2	8	Completed	All Campuses
5	Others (mixed purpose buildings)	≥G+2	9	Completed	All Campuses
ON-PROGRESS BUILDINGS					
1	AU Referral and Teaching Hospital	2B+G+5	1	On-progress	Main Campus
2	Classroom, Lab, Office (3 wings)	G+5	1	On-progress	Main Campus
3	President Office	G+6	1	On-progress	Main Campus
4	Main Administration, Awaro (5 Wings)	G+3	1	On-progress	Awaro Campus
5	Classroom and Clinic	G+4	2	On-progress	Guder Campus
6	Classroom, lab, Office (3 wings)	G+5	1	On-progress	Woliso Campus

TABLE II

GENERAL PROFILE OF CONTRACTORS AND CONSULTANTS

CONTRACTORS			
S. No.	Company Name	Projects	Location
1	TNT Trading and Construction	Referral Hospital	Main Campus
		Main Administration	Awaro Campus
2	Flint Stone Engineering	Staff Residence	Awaro Campus
		Staff Residence	Guder
		President Office	Main Campus
3	Yotek	AU Expansion,	Ambo & Guder
		Classroom, dormitory, Office	
4	MCG Construction Plc.	Classroom, Lab, Office	Main Campus
5	Tekle Birhan Ambaye	Classroom, dormitory, Office	Main Campus
6	Libu Kifle BC	Dormitory, classroom, Clinic	Awaro, Guder
7	Samket Engineering	Classroom, Lab, Office	Woliso Campus
8	Antneh Mohammed BC	Dormitory, Seminar, classroom	Awaro Campus
9	Wayuma Gemessa BC	Dormitory	
10	Atinafu Ashine BC	Dormitory	Awaro Campus
11	Icon Construction Plc	Veterinary Clinic	Guder Campus
12	Tolif Construction	Daycare School	Main Campus
13	Barecha Fitta BC	Library	Awaro Campus
14	Tesfaye Abebe BC	Dormitory	Woliso Campus
15	Asnake Teshome BC	Dormitory	Woliso Campus
17	Horata Engineering	Dormitory, Lecture Hall	Awaro Campus
18	Jemal Fanta BC	Auditorium, Dormitory, Seminar	Guder Campus
19	Guta Lemecha BC	Dormitory	Guder Campus
20	Justice Construction PLC	Dormitory	Awaro Campus
21	Andersa Jote	Referral Hospital and main campus maintenance	Ambo
22	Fanta Negash B.C	Seminar, classroom	Awaro Campus

23	Bios Construction PLC	Lecturer hall, DAB	Awaro Campus
24	Ansif Seyum BC	Laboratory	Guder Campus
25	Rift Valley Construction	Dormitory	Guder Campus
26	Lemma Edae BC	Seminar, classroom	Awaro Campus
CONSULTANTS			
1	MH Engineering		
2	CDSWC		
3	K2N		
4	BED		
5	Project Administration Team (AU)		

D. Reliability Test

According to [12], any measurement-based research must consider reliability. Reliability concerns whether the data collection and analysis procedures produce consistent results and whether others can make similar observations and draw the same conclusions from the same raw data. That is, data collection procedures can be repeated with the same results. Lee Cronbach developed Cronbach's Alpha in 1951 to assess a test's internal consistency; it is always expected to fall between 0 and 1. The measurement system was created to measure a specific concept by asking a group of people a series of questions (items). Internal consistency is defined as the extent to which all questions positively contribute to measuring the same concept or construct [12, 13, 14]. Besides, internal consistency is expressed as the proportion of the test variance attributable to a group of items, which measures the reliability coefficient alpha [13].

$$\propto = \frac{I}{I-1}\left(1 - \frac{\sum_{i=1}^{I}\sigma_I^2}{\sigma_X^2}\right) \tag{1}$$

Where: I = Number of Items

σ_I^2 = variant items

σ_X^2 = total score variant

A high value of the Cronbach's alpha implies a higher internal consistency of the construct σ_X^2. The higher the coefficient, the stronger the linear relationship of the items is correlated and the higher the internal consistency cited by [13, 14]. On the other hand, [15] provide the following rules of thumb: "_ > .9 – Excellent, _ > .8 – Good, _ > .7 – Acceptable, _ > .6 – Questionable, _ > .5 – Poor, and _ < .5 – Unacceptable". While increasing alpha depends on the number of items in the scale, there are diminishing returns [16]. Because Cronbach's alpha coefficient is the most widely used objective measure of reliability, the internal consistency of the scale of data reliability (data collected via a questionnaire) was checked before the analysis of the study.

E. Validity Test

[12] defines validity as the degree to which the instrument measures what the researchers want to measure. Validity is the most important criterion that indicates how well an instrument measures what it is supposed to measure. It was verified the content validity of the research by examining the questions and measurement scales. A pilot test of the questionnaire was given to some respondents. Checking the clarity, length, structure, and wording of the questions was also done. As a result of the test, the researcher was able to revise.

F. Data Analysis

The relative index methods were used to analyze the questionnaire data. Using the frequency analysis, the relative index ranked the importance and practicability of each performance measure using the given formula below [14, 17].

$$RII = \frac{\left(5n^5 + 4n^4 + 3n^3 + 2n^2 + n\right)}{5\left(n^5 + n^4 + n^3 + n^2 + n\right)} \tag{2}$$

Where: RII = represents Relative Importance Index

n^5, n^4, n^3, n^2 & n= represents number of indicators of answer.

Computation with the Relative Importance Index (RII) provides a value between 0.2 and 1.0. The 0.2 value represents the lowest strength, and the 1.0 value the highest strength value. The data obtained from questionnaire surveys and desk studies are qualitatively and quantitatively analyzed, evaluated, and interpreted.

III. RESULTS AND DISCUSSION

A. Data from a questionnaire, factors affecting building construction materials and workmanship

The contractors, consultants, and customers have been provided with a well-structured questionnaire and distributed it. All consultants and contractors involved in AU Buildings have been taken into account. In the course of the research, AU construction was participated by 26 contractors and 3 consultants. Ninety questionnaires were distributed, and from these, only 77 questionnaires were returned (26x3=78 contractors, 3x3=9 consultants, and 1x3=3 clients). The questionnaire validity is determined on the basis that the replies as adequate. i.e., questionnaires are deemed invalid without replies and partial replies. 71 of the 77 questionnaires received were therefore considered valid, showing a response rate of 78.9%.

TABLE III

QUESTIONNAIRE RESPONSE RATE

Description	Respondents %)			Total (%)
	Contractors	Consultants	Client	
Questionnaires distributed, (A)	78	9	3	90
Questionnaires retrieved	69	7	1	77
Valid responses, (B)	63	7	1	71
Response rate (valid), (C) = (B/A)*100	80.80%	77.80%	33.30%	78.90%

Nineteen site engineers, seventy office engineers, fourteen project managers, two architects, eight resident engineers, and eleven senior engineers have been observed from the returned questions among the total respondents.

TABLE IV

RESPONDENTS WORKING POSITION

Respondents Working Position			
S. No	Position	No.	Percentage (%)
1	Site Engineer	19	26.80
2	Office Engineer	17	23.90
3	Project Manager	14	19.70
4	Architect	2	2.80
5	Resident Engineer	8	11.30
6	Senior Engineer	11	15.50

There were 26 contractors, 2 private consultants, 1 governmental and private partner consultant, and 1 state employer concerning company type and ownership (client). The table below summarizes the working experience of companies in the Ethiopian construction and building industries in different years.

TABLE V

WORK EXPERIENCE OF ORGANIZATIONS

Work Experience of Organizations					
In the Ethiopian construction industry (in a year)			In the building construction sector (in a year)		
Experience (No. of years)	Organizations by:		Experience in year	Organizations by:	
	No.	Percentage (%)		No.	Percentage (%)
0 – 5 years	4	13.30	0 – 5 years	4	13.30
6 –10 years	9	30.00	6 –10 years	9	30.00
11 – 15 years	8	26.70	11 – 15 years	8	26.70
More than 15 years	9	30.00	More than 15 years	9	30.00

Table VI summarizes the work experience of the individual respondents in the Ethiopian construction industry and the building construction sector by years separately.

TABLE VI

WORK EXPERIENCE OF INDIVIDUAL RESPONDENTS

Work Experience of Individual Respondents					
In the Ethiopian construction industry (in a year)			In the building construction sector (in a year)		
Experience (No. of years)	Respondents by:		Experience in year	Respondents by:	
	No.	Percentage (%)		No.	Percentage (%)
0 – 5 years	12	16.90	0 – 5 years	17	23.90
6 –10 years	35	49.30	6 –10 years	34	47.90
11 – 15 years	13	18.30	11 – 15 years	11	15.50
More than 15 years	11	15.50	More than 15 years	9	12.70

TABLE VII

ORGANIZATIONS PRACTICE MATERIALS QUALITY CONTROL AND WORKMANSHIP

Phrases that best define quality			Self-performance judgment on constructed buildings		
Phrases that best define quality	Responses		Self-performance judgment	Responses	
	Frequency			No.	In percent (%)
Expensive materials	7		Excellent	5	7.04
Appearance/ Aesthetics	31		Very good	58	81.70
Increased profit	24		Good	8	11.26
Customer's satisfaction	54		Satisfactory	0	0
Meeting specification requirement	66		Poor	0	0
Organization quality management system			Degree of compliance with BOQ or Specification		
Organization quality management system	Responses (firms)		Degree of compliance with BOQ or spec	Responses	
	No.	In percent (%)		No.	In percent (%)
ISO	4	13.33	More than 90 %	67	94.36
TQM	11	36.67	80 - 90%	4	5.64
QA/QC	15	50.00	70 - 80%	0	0
			less than 70%	0	0

Most contractors and consultants use many mechanisms to monitor and verify compliance with technical specifications in the construction of projects. The testing and examination shall check 93% of the materials reported on the questionnaire, and the remaining seven percent was checked according to the respondents using the manufacturer's catalog.

B. Major variables that could affect building construction materials quality and workmanship of the project

Internal consistency of data describes the extent to which all items in an instrument measure the same concept. The internal consistency of the collected data was first tested using the Cronbach's alpha coefficient formula described under the reliability test. Following this, the Cronbach's coefficient for contractors and consultants was 0.812 and 0.753, respectively. As a result, the Cronbach's coefficient values for all parties are above 0.70, proving validity. Using this evidence, all survey data were analyzed. After verifying the survey data's reliability, the relative importance index method was used to rank material and construction quality factors. A comprehensive literature review identified fifteen major factors affecting building construction materials' quality and workmanship. A well-structured questionnaire was created to collect professional views and experiences from the respondents on these significant factors.

TABLE VIII

MAIN FACTORS AFFECTING MATERIALS QUALITY AND WORKMANSHIP

No.	Main factors affecting materials quality control and workmanship	Degree of Importance					Total	RII	Rank
		5	4	3	2	1			
1	Applicability of Building Regulations	31	19	21	0	0	298	0.84	4
2	Factors related to Design	28	36	7	0	0	305	0.86	2
3	Factors related to Specification	22	41	7	1	0	297	0.84	4
4	Factors related to Management	37	28	6	0	0	315	0.89	1
5	Factors related to Nature of Materials	33	29	6	2	1	304	0.86	2
6	Factors related to Labors	28	28	12	3	0	294	0.83	5
7	Factors related to Site Access	9	27	32	2	1	254	0.72	8
8	Factors related to Financial	27	32	11	1	0	302	0.85	3
9	Factors related to Site staffs	36	26	5	4	0	307	0.86	2
10	Factors related to Weather conditions	24	25	16	6	0	280	0.79	6
11	Factors related to Technical issues	6	14	45	2	4	229	0.65	10
12	Factors related to Materials Testing and Inspection	38	27	5	1	0	315	0.89	1
13	Factors related to Project Nature	21	18	31	0	1	271	0.76	7
14	Factors related to Equipment	9	23	35	3	1	249	0.7	9
15	Factors related to Knowledge of Implementing Rules & Regulations of the Government Procurement Law	7	14	13	31	6	198	0.56	11

As shown in Table VIII, the respondents identified and ranked the main variables affecting building construction materials' quality and workmanship. The respondents ranked the factors related to management, materials testing, and inspection with RII = 0.89. Project management is critical to achieving quality projects in all phases. Material testing and inspection are important activities that directly check material's compliance with specifications and standards. The design, materials, and site staff variables were ranked second with an RII of 0.86. As the foundation for subsequent construction activities, design influences both material, and workmanship quality. The material used directly affects the project's quality. The commitment of the site staff is critical to the project's quality control and workmanship. Financial factors are ranked third with RII = 0.85, followed by Applicability of Building Regulations and Specification Factors with RII = 0.84. The remaining variables have RII of 0.83, 0.79, 0.76, 0.72, 0.70, 0.65, and 0.56.

1) Factors related to management

It includes good project managers, foremen, superintendents, and others. The project manager's knowledge of materials and workmanship impacts the overall project. Consultant full-time involvement and Strict and professional control of all project workers rank first and second with RII of 0.92 and 0.90, respectively. Qualified projects result from competent construction consultants who are excellent planners with strong material specification skills. All workers on the project should be qualified and meet quality standards. A single unqualified worker can derail an entire project. Contractor attention on materials quality and workmanship are ranked third by respondents with RII = 0.89. The Contractor will be doing the work on-site, so quality materials and workmanship are important. The professionalism of managers and coordinators and Consultant-Contractor Collaboration rank fourth and fifth with RII of 0.84 and 0.83. Communication within an organization and on-site is to influence the actions/behaviors of others or to exchange or request information during a construction project.

TABLE IX

FACTORS RELATED TO MANAGEMENT

No.	Sub-factors related to management	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Cooperation between consultant and Contractor	29	24	18	0	0	295	0.83	5
2	Consultant full-time involvement	47	21	3	0	0	328	0.92	1
3	Contractor attention on materials quality	41	23	6	1	0	317	0.89	3
4	Contractor attention on workmanship	39	27	4	1	0	317	0.89	3

5	Strict and professional control of all workers on the project	45	18	8	0	0	321	0.9	2
6	Professional capability of respective managers and coordinators	29	28	13	1	0	298	0.84	4

2) Factors related to Materials Testing and Inspection

Material testing and inspection are vital in quality control. All materials must pass tests and inspections to meet specifications. PILING INSPECTIONS: vibration monitoring, ground-penetrating radar (GPR), pre and post-construction surveys, and settlement plate. Testing frequencies and tolerances, daily production records, inspection, and verification are sub-factors with RII values of 0.84. Defects or non-compliance should be reported. Certified technician testing was second with 0.82 RII. Certified technicians should perform all required tests. With an RII of 0.81, respondents ranked having an on-site lab third. The remaining materials testing and inspection issues have RII of 0.80, 0.77, and 0.74. Construction and material quality control rely on them.

TABLE X

FACTORS RELATED TO MATERIALS TESTING AND INSPECTION

S. No	Sub-factors related to Materials Testing and Inspection	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Availability of lab at the site	23	27	21	0	0	286	0.81	3
2	Independent certification by an approved body	19	24	18	8	2	263	0.74	6
3	Sampling and testing procedures	24	22	18	6	1	275	0.77	5
4	Testing frequencies and tolerances	35	21	11	3	1	299	0.84	1
5	Daily production records	31	23	17	0	0	298	0.84	1
6	Testing by certified technicians	31	22	14	3	1	292	0.82	2
7	Inspection and Verification	35	21	11	2	2	298	0.84	1
8	Calibration of Instruments used for testing	26	22	21	2	0	285	0.8	4

3) Factors related to design

Design is vital in construction projects as it serves as a master requirement plan and specifications. Non-functional design can impede activities, detract from the quality, and raise costs to unacceptably high levels. Like Newton's third law of motion, every design decision/consideration has consequences. During the design phase, all drawings should be detailed, consistent, and complete. With RIIs of 0.82 and 0.80, respondents ranked drawing preparation first, followed by design document completeness and consistency. Design conformance to codes and standards and practice and accuracy of the bill of quantity also gain 0.74 and 0.70 RII. Materials and workmanship quality control are essential sub-factors of the design variable.

TABLE XI

FACTORS RELATED TO DESIGN

S. No	Sub-factors related to design	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Completeness and consistency of design documents	25	28	12	4	2	283	0.8	2
2	Drawings are prepared in details	31	23	11	6	0	292	0.82	1
3	Design conformance to codes and standards	18	27	16	8	2	264	0.74	3
4	Bill of quantity is detailed and accurate	14	18	29	8	2	247	0.7	4

4) Factors related to Nature of Materials

The respondents ranked eight important issues under the nature of materials based on their importance. It is the first important sub-factor that can affect the quality and workmanship of building projects. The RII is 0.86. To be environmentally friendly, construction materials must be highly durable and sourced locally. Strength and durability, Availability of materials as approved plan, Attack resistance (e.g., fire, heat, water, chemicals, weather action), Flexibility of materials on work, and Availability of material suppliers also have RII values of 0.85, 0.81, 0.79, 0.76, 0.68, and 0.66. The respondents rank them according to their importance for quality control and workmanship. All of the issues mentioned above play a role in the execution of building projects.

TABLE XII

FACTORS RELATED TO NATURE OF MATERIALS

S. No	Sub-factors related to Nature of Materials	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Availability of materials as approved plan	29	25	11	4	2	288	0.81	3
2	Availability of material suppliers	13	16	27	9	6	234	0.66	7
3	Sustainability of materials	34	24	12	1	0	304	0.86	1
4	storage and handling system	33	27	10	1	0	305	0.86	1
5	Flexibility of material on work	17	28	22	3	1	270	0.76	5
6	Attack resistance (e.g. fire, heat, water, chemicals, weather action)	23	22	24	2	0	279	0.79	4
7	Strength and durability	31	27	13	0	0	302	0.85	2
8	Affordability of materials	12	19	28	10	2	242	0.68	6

5) Factors related to Site staffs

Construction firms have their own organizational structure. Because each project has its own context and content, roles and responsibilities will vary greatly. The involvement of workers is critical. It is ranked 1–6 in terms of supervisory skill and experience, contractor skill and experience, supervisory dedication (continuous follow-up work), and supervisory understanding of contract administration. The supervisory and Contractor staffs' RIIs are 0.90 and 0.85, respectively. The third was work commitment (constant supervision) (RII 0.84).

TABLE XIII

FACTORS RELATED TO SITE STAFF

S. No	Sub-factors related to Site Staffs	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Cooperation between Supervision and Contractor's staffs	26	32	13	0	0	297	0.84	4
2	Understanding of contract administration by Supervision	23	28	17	3	0	284	0.8	6
3	Skill and experience of Supervision staff	43	22	5	1	0	320	0.9	1
4	Skill and experience of Contractor's staff	32	26	13	0	0	303	0.85	2
5	Dedication of supervision staffs (continuous follow up of work)	35	19	14	2	1	298	0.84	3
6	Dedication of contractor staff (continuous follow up of work)	31	18	18	4	0	289	0.81	5

6) Factors related to Financial

In Table XIV, payment delay ranked first with 0.86 RII. Then comes a 0.82 RII material price increase. One of the significant challenges facing the construction industry is rising material costs. In Ethiopia, the construction sector is burdened by rising construction material and input costs and domestic and global inflation. Overtime cost, contractor cash flow, and labor cost escalation ranked third, fourth, and fifth with RII of 0.75, 0.74, and 0.70. Project delays result in cost overruns, and labor cost increases harm the project.

TABLE XIV

FACTORS RELATED TO FINANCIAL

S. No	Sub-factors related to financial	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Escalation of materials price	31	23	12	3	2	291	0.82	2
2	Escalation of labor cost	13	27	16	12	3	248	0.7	5
3	The amount of Contractor's cash flow	17	26	18	10	0	263	0.74	4
4	Delay of payments	36	22	11	2	0	305	0.86	1
5	Project overtime cost	19	26	19	5	2	268	0.75	3

7) Factors related to Applicability of Building Regulations

Building codes and standards, both international and local, are critical to successful projects. They are designed to ensure that the construction policies set out in the relevant legislation are followed and to establish harmonized construction laws. TQM, QA, and QC applications had 0.86 RII. Applicability of BOQ (Contract), Specifications, EBCS, and ISO ranked second, third, fourth, and fifth with RII values of 0.78, 0.77, 0.69, and 0.64. Contract Documents are the written documents that define the roles, responsibilities, and "Work" under the construction contract and are legally binding on the parties.

TABLE XV

FACTORS RELATED TO APPLICABILITY OF BUILDING REGULATIONS

S. No	Sub-factors related to Applicability of Building Regulations	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Applicability of ISO	6	13	44	5	3	227	0.64	5
2	Applicability of EBCS	17	13	27	13	1	245	0.69	4
3	Applicability of Specifications	24	22	19	4	2	275	0.77	3
4	Applicability of BOQ (Contract)	23	28	9	11	0	276	0.78	2
5	TQM, QA, QC applications	37	24	5	5	0	306	0.86	1

8) Factors related to specification

Specifications are part of the contract documents that govern the project's performance. Because specifications influence all aspects of a construction project, clear specifications and a shared understanding of their intent by all parties lead to better projects. To avoid change orders and other misunderstandings, all materials and work must be specified accurately. Preparation of specifications for all materials ranked first with an RII of 0.84. It is followed by the preparation of Separate specifications other than BOQ, which has 0.80 of RII. The other sub-factors are Availability of full specification, Specification consistency with drawings, Specification for all necessary tests of materials and workmanship, Change order (Addition, Subtraction, or alteration), and Mistakes in quantity survey are having 0.78, 0.78, 0.75, 0.68, 0.61 RII respectively. Generally, the specification document serves as the backbone of the entire project.

TABLE XVI

FACTORS RELATED TO SPECIFICATIONS

S. No	Sub-factors related to specification	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Availability of full specification	22	31	9	8	1	278	0.78	3
2	Specification for all materials and works	36	22	7	3	3	298	0.84	1
3	Specification consistency with drawings	25	20	19	7	0	276	0.78	3
4	Specification for all necessary tests of materials and workmanship	21	21	18	11	0	265	0.75	4
5	Separate specification other than BOQ	22	30	17	2	0	285	0.8	2
6	Change order (Addition, Subtraction, or alteration)	9	20	35	3	4	240	0.68	5
7	Mistakes in quantity survey	7	18	21	23	2	218	0.61	6

9) Factors related to labors

Project managers must pursue efficient labor utilization. Those in charge of quality and cost control of built facilities should constantly strive to improve labor productivity. The involvement of at least one chief worker in their respective work is very important to produce projects of required quality and pleasing workmanship. Labor communication skills and training or workshops are important sub-factors that can contribute to the project if implemented correctly. Proportional income is one of the motivational systems that could be used to improve labor productivity. Recruiting skilled and trained workers is required to complete a job professionally. Labor experience, involvement of at least one chief worker in respective works, and labor communication skills are ranked first to third with RII of 0.88, 0.86, and 0.84, respectively. The remaining issues are labor training, motivation, and income and wages, with RII values of 0.81, 0.74, and 0.64. Since workers perform all activities, most defects in construction projects are caused by human errors, specifically poor workmanship.

TABLE XVII

FACTORS RELATED TO LABORS

S. No	Sub-factors related to Labors	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Communication skills of labor	23	41	5	2	0	298	0.84	3
2	labors experience	41	19	9	1	1	311	0.88	1
3	Involvement of at least one chief worker in respective works	36	21	14	0	0	306	0.86	2
4	Motivation System	18	21	28	1	3	263	0.74	5
5	Training or workshop for labors	26	29	12	2	2	288	0.81	4
6	Income level and wages of labors	11	14	32	7	7	228	0.64	6

10) Factors related to Weather conditions

Extreme weather can impact construction timelines and materials. Even in Ethiopia, where extreme weather is rare, construction can be complex, especially in the summer. Snow and ice can damage materials and machinery and pose safety risks to workers. The rainy season can affect the quality of construction materials and workmanship. Even if the remaining sub-factors aren't common, they affect building construction. That's why it came first. Its RII is 0.56 for humidity, 0.53 for Prevailing Wind, and 0.50 for out of Range Temperature.

TABLE XVIII

FACTORS RELATED TO WEATHER CONDITIONS

S. No	Sub-factors related to Weather Conditions	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Rainy season	10	15	29	14	3	228	0.64	1
2	Out of the range Temperature	3	12	19	22	15	179	0.5	4
3	Prevailing Wind	7	9	18	27	10	189	0.53	3
4	Humidity	9	14	19	11	18	198	0.56	2

11) Factors related to Project Nature

The main issues listed under project nature are budget, duration, scope, site accessibility, and location. These are the major ones, but there may be others. Budgets for project construction are prepared and approved prior to a defined period to achieve a given objective. Budgets should be set as early as possible, based on evidence, and be realistic. The size and accessibility of a project are important factors in material selection and workmanship. The project budget was ranked first, followed by the project period (RII 0.79). The project's scope ranked third with an RII of 0.74, and its accessibility and location ranked fourth and fifth with RIIs of 0.68 and 0.65.

TABLE XIX

FACTORS RELATED TO THE PROJECT NAME

S. No	Sub-factors related to Project Nature	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Scope of the project	16	26	20	8	1	261	0.74	3
2	Location of the project	9	18	31	7	6	230	0.65	5
3	Site accessibility	10	22	29	7	3	242	0.68	4
4	Period of the project	25	23	17	4	2	276	0.78	2
5	Budget of the project	27	22	13	9	0	280	0.79	1

12) Factors related to Site Access

All sub-factors listed under site access have an impact on materials and workmanship quality. Materials should be stored in a planned manner and handled with care by all workers. Material handling involves the delivery, movement, storage, and control of materials and other products. It was followed by site distance from material suppliers (RII 0.67). Material delivery and supplier distance affect material quality. The other issues are working site cleanliness, site layout size (too small or too large to store and handle materials), and site suitability (to perform good quality workmanship), with RII of 0.64, 0.62, and 0.59, respectively.

TABLE XX

FACTORS RELATED TO SITE ACCESS

S. No	Sub-factors related to Site Access	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Cleanliness of the working site	9	13	35	11	3	227	0.64	3
2	Site layout or orderly for material storage/ handling	21	31	13	4	2	278	0.78	1
3	Size of site layout, i.e., too small or too large to store and handle materials	6	14	36	12	3	221	0.62	4
4	Site distance from material supplier's	12	15	29	15	0	237	0.67	2
5	Suitability of site to perform good quality workmanship	8	7	33	21	2	211	0.59	5

13) Factors related to equipment

The equipment management system impacts the project's quality and workmanship. Construction equipment can improve product quality, project efficiency, cost savings, profitability, and site safety. Choosing the right construction equipment and qualified operator is crucial. Equipment efficiency was identified as the most critical sub-factor, followed by operator experience and performance. The third and fourth important sub-factors are equipment technology, cost, and quality. Their RII values are 0.80, 0.75, 0.72, and 0.71, respectively.

TABLE XXI

FACTORS RELATED TO EQUIPMENT

S. No	Sub-factors related to equipment	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Equipment efficiency	24	29	13	5	0	285	0.8	1
2	Operator experience and performance	21	21	19	9	1	265	0.75	2
3	Quality of Equipment	12	27	22	7	3	251	0.71	4
4	Technology and cost of Equipment	15	23	25	6	2	255	0.72	3

14) Factors related to Technical issues

The study's technical issues concern finishing works and related operations. Each of the sub-factors discussed here has an RII of 0.72, 0.69, 0.61, and 0.56. These issues affect material quality, workmanship, and even building performance. Workability is the quality of being workable, practical capacity to succeed, and how easily the material can be operated in a required way. The more workable materials used, the more qualified the building project is operated. The building's external and internal faces require pleasing materials, and they should be considered during design and construction. The final project's maintenance level, color, and texture were carefully considered.

TABLE XXII

FACTORS RELATED TO TECHNICAL ISSUES

S. No	Sub-factors related to Technical Issues	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Appearance and aesthetic value	13	27	13	14	4	244	0.69	2
2	Color and Texture	8	11	21	22	9	200	0.56	4
3	Maintenance level	8	13	29	16	5	216	0.61	3
4	Workability level	17	23	17	12	2	254	0.72	1

15) Factors related to Knowledge of Implementing Rules & Regulations of the Government Procurement Law

Procurement management systems must adhere to government procurement laws. Defects The RIIs for the four issues discussed were 0.61, 0.56, 0.49, and 0.44. Poor materials and workmanship cause building defects. Most contracts require the

Contractor to return to the site to remedy defects during the defects liability period. A Variation Order is a written change to the contract's original scope of work. Variations often lead to poor performance and workmanship. Building construction projects require controlling variation orders to perform well—negative slippage and contract termination impact project quality.

TABLE XXIII

FACTORS RELATED TO KNOWLEDGE OF IMPLEMENTING RULES & REGULATIONS OF THE GOVERNMENT PROCUREMENT LAW

S.No	Sub-factors related to Knowledge of Implementing Rules & Regulations of the Government Procurement Law	Degree of importance					Total	RII	Rank
		5	4	3	2	1			
1	Variation Orders (Change Order, Extra Work Order)	4	13	31	11	12	199	0.56	2
2	Negative Slippage	7	11	11	21	21	175	0.49	3
3	Defects Liability period	12	16	14	20	9	215	0.61	1
4	Termination of Contract	3	8	12	25	23	156	0.44	4

According to Cronbach's alpha analysis, Cronbach's coefficients for contractors and consultants were 0.812 and 0.753, respectively. As a result, the Cronbach's coefficient values for all parties are above 0.70, proving validity. So all survey data was analyzed.

C. Analysis and discussion of data from case studies and desk studies

1) Existing (completed) buildings status analysis based on their materials quality control and workmanship

Ambo University has many buildings with various functions on all campuses. Buildings G+2 and above are examined for material quality and workmanship. Nine others (mixed purpose buildings) are investigated in addition to 30 dormitory buildings. All of these buildings have been visually inspected and identified with various flaws. It is determined that the causes of these defects are due to poor construction materials and workmanship. Table XXIV shows the major defects found in the buildings. Walls, ceilings, floors, doors, and windows had more visible and varied defects. They were observed both inside and outside the buildings chosen for the study. According to the surveyed literature, many construction materials crack with age, expand and contractions, especially when exposed to moisture. Building cracks are caused by drying shrinkage, thermal movement, elastic deformation, creep, chemical reaction, foundation movement and settlement, and vegetation growth.

TABLE XXIV

MAJOR DEFECTS OBSERVED ON EXISTING BUILDINGS

Observed Defects	Frequency of buildings having defects				
	C1 (30)	C2 (16)	C3 (5)	C4 (8)	C5 (9)
Defects on foundations, column, beam and slab					
Settlement	14	4	1	3	3
Cracks on beams, columns, slabs	9	3	2	3	2
Defects on wall, ceiling, floors, doors, windows					
Cracks on HCB walls	24	16	5	8	7
Floors and walls moisture leakage	30	9	3	2	9
Water damage on ceilings, walls, or floors	23	11	3	5	9
Ceiling and wall joint separation	12	3	2	4	4
Defective floor, wall & external finish	30	16	5	8	9
Broken or loose tiles on floors or wall	15	13	2	3	6
Shrinkage cracks on plastering	22	16	5	8	9
Paint peeling on faces of walls, columns, and beams	30	16	5	8	9
Water seepage through windows and doors	18	5	0	6	4
Tiles missing grout/sealant	11	7	2	-	4
Plastering defects	30	16	5	8	9
Chipped or cracked tiles	16	7	2	-	5
Defects on doors and windows framing	23	16	3	8	5
Defects on roofs					
Poor roof slope	10	0	0	2	3

Improperly sized and sloped gutters	10	6	2	4	3
Some downpipes have damage	21	9	3	6	7
Damaged roof sheathing	6	3	0	2	1
Defects on sanitary systems					
Shower and toilet leaks	30	12	2	3	9
Poor sanitary pipes installation	30	12	2	3	9
Broken fixtures	30	16	5	6	9
Defects on electrical systems					
Lights not working to some areas	30	16	5	7	9
Broken fixtures	30	16	5	6	9
Some outlets are not working	30	16	5	6	9

C1: Category 1 – Dormitory, C2: Category 2 – Classrooms and seminars, C3: Category 3 – Libraries, C4: Category 4 – Laboratories, C5: Category 5 – others (mixed purpose buildings)

More than half of the building blocks had visible foundation defects like settlements and cracks. The main causes of the settlement are poor compaction, weak bearing soil, moisture changes, and soil consolidation. All studied buildings had cracks in common areas such as exterior walls, interior walls at door and window corners, floors, and ceilings. General measures to protect cracks include correct specifications for mortar, concrete, and all other materials and works, good construction practices (workmanship), and avoiding construction during severe weather conditions.

Fig. 2 Cracks on structural beam and slab: classroom and dormitory, Woliso Campus

2) Based on the visual inspection made, the following crack types were identified, and their possible repair methods were suggested.

Thermal movement: It is one of the most common cracks in buildings, and it is caused by temperature variations, thermal expansion coefficients, and other physical properties of the components. It has been observed on both internal and external walls subjected to significant thermal variation and prone to cracking.

Shrinkage: Most building materials expand when wet and shrink when dry. Two main factors cause shrinkage in cement concrete and cement mortar. Excessive water in the mortar mix can cause shrinkage. The second is cement quantity: The more affluent the mix, the greater the shrinkage.

Chemical Reaction: It can occur due to the concrete's composition or materials that come into contact with it after it hardens. Concrete may crack over time due to expansive reactions between active silica aggregate and alkalis from cement hydration, admixtures, or external sources.

Elastic Deformation: Elastic Deformation occurs when a material strains under stress. When two materials of different elastic properties are built together under the effect of load, different shear stresses create cracks at the junction. Both dead and live loads are the major cause of elastic deformation in any structural component of a building.

Suggested repair methods:

***Injection of Epoxy*:** The method is very useful for repairing dormant or nonmoving cracks in slabs, walls, columns, and piers.

***Sealing and routing*:** The method is preferably used in conditions that require repair and maintenance and where repair of structures is unnecessary. In the process, the crack is enlarged along its face, which is exposed, which is followed by filling with a suitable sealant.

Dry packing: It is the process of placing low moisture content mortar, followed by tamping the placed mortar into a particular area.

Water may leak from a building's roof or floor if not built properly. Small amounts of water can cause significant issues in a building. On average, 82 percent of the structures studied had moisture leakage. Water leakage causes paint peeling, cracks, and staining, which reduces building life and performance.

Fig. 3 Moisture leakage problems: dormitory blocks, main Campus

Almost every building in the study had plastering and painting issues. The most common and frequently identified plastering defects were crazing, flaking, and peeling Using sand containing excessive amounts of dust (15% by mass), inadequate substrate preparation, insufficient cement, excessively thick layers, adding extra water too long after first mixing (re-tempering), evaporation (when plastering in sun and wind), and inadequate substrate preparation is all causes of sand failure.

Fig. 4 Paint defects observed on walls from the four campuses.

3) On-progress buildings status assessment on the basis of their materials quality control implementation and workmanship

All G+2 and higher buildings under construction on all Ambo University campuses were chosen for the study. The materials quality control and workmanship of these buildings are discussed using data from contractors, consultants, clients, site observations, and desk studies.

3.1 Assessment on AU Referral and Teaching Hospital (Building A)

The AU Referral and Teaching Hospital are one of the university's largest construction projects. Site inspections, contractor and consultant interviews, and contract document reviews were conducted to assess the stakeholders' materials quality control implementation and project work compliance with pre-set specifications and standards. Since the project is ongoing, foundations, concrete, brick, hollow concrete block, and reinforcement work has been seen.

TABLE XXV

ON-PROGRESS BUILDING PROFILE

No.	Project Name	Given name	Height	No. of Bldgs.	Status	Location
1	AU Referral and Teaching Hospital	A	2B+G+5	1	On-progress	Main Campus
2	Classroom, lab, Office (3 wings)	B	G+5	1	On-progress	Main Campus
3	President Office	C	G+6	1	On-progress	Main Campus

4	Main Administration, Awaro (5 Wings)	D	G+3	1	On-progress	Awaro Campus
5	Classroom and Clinic	E	G+4	2	On-progress	Guder Campus
6	Classroom, lab, Office (3 wings)	F	G+5	1	On-progress	Woliso Campus

According to the general technical specification document, materials and workmanship must meet technical specifications and be subject to periodic testing by the engineer (MH-Engineering, 2010). Materials must be approved or tested first. The engineer may reject damaged or deteriorated materials and remove them immediately. Despite this, the Contractor was seen using damaged materials like bricks as membranes on retaining walls. The stone masonry also didn't meet the technical requirements.

Fig. 5 Settlement and non-conforming backfill materials

The concrete strength is good, as indicated in the test results. However, the workmanship had some issues, particularly between columns and beams. These connection issues may eventually reduce building performance and increase maintenance costs. The materials delivered to the site generally match the specifications and contracts, but there was a problem with materials handling. Those built structures also had poor workmanship.

3.2 Assessment on Classroom, lab, Office (3 wings) (Building B and F)

Both Ambo University-Main Campus and Wolliso Campus buildings are still in the foundation stage. The materials quality management and workmanship of these twin buildings are discussed. The researcher has tried to obtain test results such as concrete, soil, and other submittals. However, other materials and works like reinforcement bars, backfill materials, and backfill compaction density could not be tested or inspected. Building F's foundation work was flooded due to the rainy season. The excavated area was flooded, but the Contractor was laying footings, and the rainwater will affect the building.

3.3. Assessment of President Office (Building C)

The president's office building was left with few finishing touches and ready to go during the study. The building's visible parts were inspected visually, and documents were collected and studied for its history. The material testing and inspection results were compared to the main contract document and found to be acceptable. The engineer's approvals and material and fixture submittals show the materials and fixtures used for the project. As seen on the site, the building had a few defects due to poor workmanship.

3.4 Assessment on Main Administration, Awaro (5 Wings) (Building D)

While the research is being conducted, Building D, the Awaro campus's main administration building, has various functions. Interviews, site visits, and a desk study were used to analyze the project's construction history. More than 50% of material tests and inspection documents were not obtained, making it difficult to determine if all requirements were met. A visual inspection revealed some issues with the project's workmanship: poor external wall tiling, windowsills, flooring, screenings, and other finishing work. Extra beams with no loads and no functions were seen around the roof.

3.5 Assessment on Classroom and Clinic (Building E)

The building is located in Ambo University, Guder Campus, and it was under construction while the study is conducted. Materials management like sand, gravel, marble, floor tiles and others have been observed. The Contractor was using Senkele sands without sieving and washing. As it is surveyed in the literature, Senkele sand has 14.28% silt content, which exceeded 6% based on Ethiopian Standard Specification. Coarse aggregates were used by mixing from two different-sized aggregates. Both

Contractor and consultant were not seen for a long time on the site, resulting in very poor workmanship on the project. It has been observed while the workers were placed concrete beyond the thickness and chiseling after setting.

Fig. 6 Class Room building, Guder Campus

4) Possible mitigations for the observed problems and basic recommendations for the present and future building projects

Ambo University has no defect-free building, even if the degree and type of defects vary from block to block. Several defects were noted and discussed in the previous section due to non-compliance materials and poor workmanship. The following are possible mitigation measures to prevent further damage to the buildings.

4.1 For Existing Buildings

To address the current issues with the university's building quality, qualified construction industry professionals should be appointed. All necessary non-destructive tests and visual inspections should be performed, and remedial actions should be taken based on the results. The use of hydraulic water-stop cement to repair cracks and leaks in concrete and walls requires a proper preparation. To successfully repair a crack, it must be prepared by widening it to three-quarters of an inch and removing loose debris. It can permanently stop active water leaks. Remove any suspect plasterwork. Prior to applying a suitable grade of plaster, prepare the background and apply a coat of Thistle Bond-It. F building defects should be identified and repaired promptly to avoid significant damage and costs to a building's foundation and other structural components. It is mandatory to perform all required maintenance professionally.

D) For Under-Construction Buildings

Contractors and consultants should devote their entire time to overseeing the construction of buildings. Consultants should monitor the project daily and check the work against the specifications and contract documents. All building materials and fixtures should be tested and inspected according to the manufacturer's specifications. Generally, damaged materials should be removed from the site. Only two contractors use Ambo sandstone that has been washed from the Senkele and Aleltu sites [11]. All contractors using the specified sand should sieve and wash it first. Assign at least one technician familiar with the requirements who can guide the tradesmen in material selection and work execution to achieve the required workmanship quality.

IV. CONCLUSION

The study's findings lead to the following conclusions: To meet all requirements and improve the quality of building projects, it must first identify and recognize the primary factors affecting the materials and workmanship. There are 15 primary factors affecting building construction materials quality and workmanship, each with sub-factors. All of these factors are ranked in terms of their importance in the project's overall success. Observations, desk studies, and interviews were used to assess the condition of Ambo University buildings based on their construction materials and workmanship. The findings indicated that there was no defect-free building in Ambo University, and degree and type of defects will vary. Hence, the contractors and consultants play a vital role in the success of building projects because they manage materials and labor. It is beneficial to test and inspect all materials in accordance with the standard specifications. Removing non-compliant materials from the site and only using new materials as specified in the contract documents will improve building performance and quality.

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