THE INFLUENCE OF INCOMPETENT PEOPLE TO STRUCTURAL DESIGNS OF HOUSES, ITS IMPACT ON STRUCTURAL FAILURES AND WAYS TO OVERCOME IN THE CONTEXT OF HOUSE CONSTRUCTION INDUSTRY

Chandana Wanniarachchi

(158991V)

Degree of Master of Science

Department of Civil Engineering

University of Moratuwa

Sri Lanka

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By

Chandana Wanniarachchi

(158991V)

Supervised by

Prof. Chintha Jayasinghe

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Department of Civil Engineering

University of Moratuwa

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DECLARATION

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Date: 07 March 2020

The above candidate has carried out research for the Masters dissertation under my supervision.

……..

Research Supervisor

Prof. Chintha Jayasinghe

Senior Lecturer

Date: ……..

ABSTRACT

Sri Lankan Construction industry has been concentrating its capacity for large scale development project while incompetent personals have been dominating the small-scale housing construction in the contemporary context. It has been a huge threat to the construction industry and for its goodwill where these incompetent people will represent the same industry and showcase bad impression to society due to lack of capabilities in the structural designs of buildings. Traditional house construction was based on those traditional construction practitioners and the labors that were exposed to structural building construction during their carrier. The clients also have the mentality of awarding the construction project to the labors that they have more control and more laymen level communication. They don't feel the communication gap and the interaction level difference with their personal interaction.

The lack of structural concerns for the construction of house have been lead to more structural failures in the present context due to the vast variation in the site conditions and loading pattern due to modern conditions in the country such as unavailability of lands with good soil conditions, use of new technical equipment in houses, modern use patterns of space in houses etc. Experts have been identified that these will lead to structural failure with high impact than earlier. The main four factors have been suggested by the researcher for the structural failure of the houses. They are Clients lack of knowledge and misunderstandings, Labors lack knowledge and manipulations seeking advantages, Engineers lack knowledge and experience, Engineers lack of confidence and communication skills. Research has been identified that Labors lack of knowledge and manipulations seeking advantages was the main factor that has a strong relationship with the structural failure as per the regression analysis was done using the survey data. Client's lack of knowledge and misunderstanding and Engineers lack of knowledge and experience have been considered as the next priority cause for the same. But Engineers lack of confidence and communication skills was not being able to prove as a factor for effecting structural failures of houses. It was recommended that clients should be more careful when constructing a house about structural practices. The engineers and the labors should have cohesiveness in working together to achieve the common goal of quality product at the end of the construction. Awareness about the

structural practices, in general, can mitigate many misunderstandings and future failures of houses in term of structure.

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CHAPTER 01

1. INTRODUCTION

1.1. INTRODUCTION

The construction industry is one of the fastest mounting and the most significant industries around the world that contributed towards the socio-economic growth in the country. It is a branch of the commercial enterprise concerned with the construction of buildings, bridges, roads and etc. (Drewer, 1980). Precisely, there is no consensus definition of construction. It can be simply defined as the process of constructing a building or infrastructure (Raftery, Pasadilla, Chiang, Hui, & Tang, 1998). It starts with planning, design, and financing and then it continues until the project is built and ready for use.

Building construction is a unique technique of the construction industry and it is involved in the assembly and erection of structures, primarily those used to provide shelter (Miles & Neale, 1991). Today, building construction plays a significant part in the industrial culture and a manifestation of its diversity and complexity to serve the diverse needs of society.

Housing construction is also a unique part of the building construction and it is a fundamental need for civilized living in any kind of society. It has been parallel to the gradual development of civilization and culture in any country and the population increase, urbanization, planning, controls and vastly the changing expectations of people produce pressure for changes in housing designs and erection methods from time to time (Henilane, 2016).

Generally, large scale construction requires collaboration across multiple disciplines and consists of lots of professionalism. Accordingly, a project manager normally manages the construction project and construction manager, structural engineer, construction engineer, and architect supervise it. They involve with the design and execution about the zoning requirements, the environmental impact of the project, scheduling, budgeting, construction safety, availability and transportation of materials, logistics and inconvenience to the public caused by construction delays and bidding. However, the professional involvement for the

small-scale construction is very much minimum especially for housing construction in the Sri Lankan context. People's attitude towards the building a house has been a totally personal work and commitment rather than a professional and planned process of work. It is a common practice that houses are being constructed by the client, obtaining a service from a set of labors, including skilled and unskilled labors such as masons and carpenters. Most of the time, the scope of the architect, consultant, and even supervisory roles are also conducted by the client or person who owns the house. The house construction work is carried out by craftsmen with his exposure. Most people tend to consider the opinion of the craftsmen with his experience without consulting a professional, having a traditional mind-set. Accordingly, in general, the client prepares architectural drawings with the help of professional architecture or draftsmen. Subsequently, he deploys a gang of labors to carry out the construction of aforesaid work under the supervision of himself and head of the labor gang. The client does not obtain services of professional structural designers and engineers in designing works involved in the house construction. Consequently, most of the situations, structural design or rather arrangement of reinforcements and sizing of sections are done by either client or labor gang leader. Sometimes, though structural drawings available and professionals are being consulted, labors or leader of them manipulate given design and instructions. Practicing this type of instructions and directions provided by incompetent people lead to a lack in the structural design and structural failures in house construction and it has been very common in this industry and society.

Accordingly, this research focuses to investigate the influence of incompetent people to structural designs of houses, its impact on structural failures and ways to overcome in the context of the house construction industry.

1.2. RESEARCH PROBLEM

How to minimize structural failures in the house construction industry due to the influence and controlling power of incompetent labors in the structural subject?

1.2.1. Problem Justification

Houses are one of the necessary factors for a human being for survival and betterment of life. People spend their hard earnings, maybe earnings of 10 – 15 years, sometimes lifetime earnings to build their dream house. In Sri Lankan cultural perspective, building an own house is an indispensable factor to be a respectable person in the society.

However, it seems that people do not follow proper methodology or do not approach in a systematic and convincing way of spending their hard earnings to build their dream house. Most of the situations, they completely rely on incompetent labors for structural matters of the houses instead of the professional structural engineers. The ultimate result is much bitter when they encounter the problems such as failure of structure of the house that they built by spending hard-earned money through the lifetime. Consequently, it is opened for the risk factor which is the high probability of collapsing such structures damaging property and lives within and nearby. Therefore, it is necessary to justify the people hard earnings spending on houses in a proper and systematic manner while securing property and lives of them and of the society as a whole, which also ensure sustainable growth and progress in the house construction industry.

Accordingly, this research attempts to identify the factors for minimizing the structural failures in the house construction industry due to the influence and controlling power of incompetent labors in the structural subject.

1.2.2. Conceptual Framework

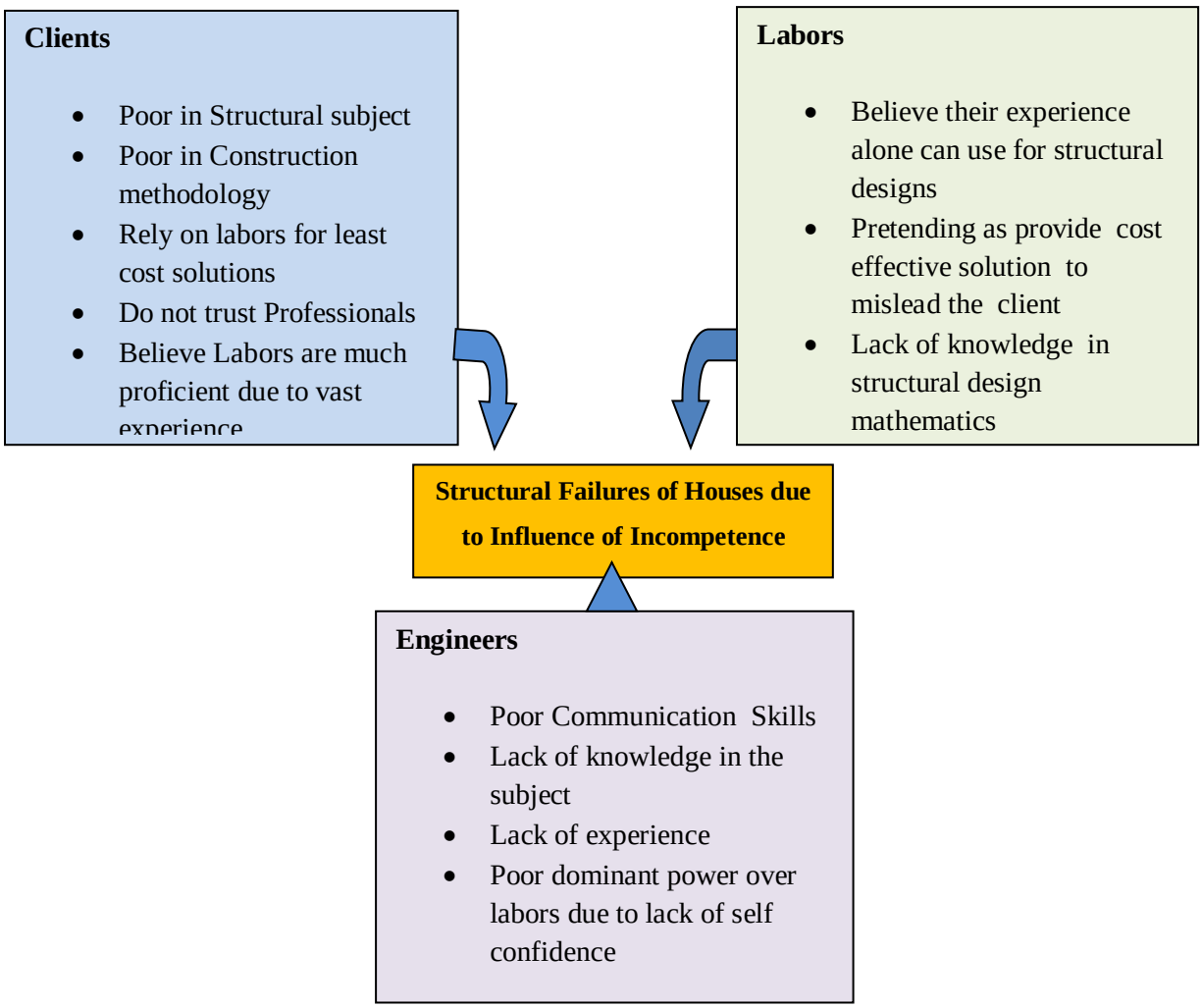


Figure 1: Conceptual Framework

With the help of secondary data which was collected from the past literature, the above conceptual framework has been drawn by using the factors which are caused for the influence of incompetent people to structural designs of houses. A hypothesis is derived with the help of the above conceptual framework in order to identify the relationship and attributes of them and at the end operationalization of the research objectives.

1.2.3. Hypothesis

As mentioned above, a hypothesis is formulated using the conceptual framework based on secondary data which was collected from the past literature such as research papers, books,

articles, and internet sources. Validation of the hypothesis is done using the data which is collected through the questionnaire survey. Results of the analysis generate the relationship of the affected factors and their attributes towards the influence of incompetent people to structural designs of houses. There are four hypotheses:

Table 1: Hypothesis

H1	H1a; Structural failures are due to Clients lack of knowledge and misunderstandings
	H1o; Structural failures are not due to Clients lack of knowledge and misunderstandings
H2	H2a; Structural failures are due to Labors lack of knowledge and manipulations seeking advantages
	H2o; Structural failures are not due to Labors lack of knowledge and manipulations seeking advantages
H3	H3a; Structural failures are due to Engineers lack of knowledge and experience
	H3o; Structural failures are not due to Engineers lack of knowledge experience
H4	H4a; Structural failures are due to Engineers lack confidence and communication skills
	H4o; Structural failures are not due to Engineers lack confidence and communication skills

As stated in the conceptual framework and the hypothesis, there are four major influences have been identified as effect to structural failures of houses. They are;

- Clients lack knowledge in the subject and misunderstandings
- Labors lack knowledge in the subject and manipulation, seeking advantages
- Engineers lack of knowledge and experience
- Engineers lack of confidence and communication skills

1.3. RESEARCH OBJECTIVES

The main objective of this research is;

- To find out the optimizing process and solution to avoid or minimize structural failures by the intervention of the incompetent people to structural designs of houses

The sub-objectives are;

- To identify the influence of incompetent people to structural designs of houses
- To understand the degree of individual factors' impact on structural failures
- To identify the route cause for structural failures in houses
- To identify the factors for minimizing the structural failures in houses

1.4. METHODOLOGY

The comprehensive literature review was carried out to explore the theoretical status and research issues. The survey research methodology was adopted to explore the influence of incompetent people to structural designs of houses, its impact on structural failures and ways to overcome in the context of the house construction industry. The explanatory research design was carried out to identify the existing factors for structural failures in the house construction industry due to the influence and controlling power of incompetent labors in the structural subject. The structured questionnaire survey was the data collection techniques of this study. Sample of 45 respondents (clients, engineers, labors) was selected for primary data collection. The data and information which were obtained from the primary and secondary sources were processed using the SPSS computer package for the quantitative data analysis. Similarly, frequency tables, simple percentage, and descriptive statistics were also used.

1.5. SIGNIFICANCE OF THE STUDY

There are two main significances in this study. The first is in its academic importance and it may fill a major gap in the literature. There are no sufficient literature regards on the structural designs and its failures of the house construction industry in Sri Lanka. Also, the practical significance of the study is that it may help to address the solutions of structural failures in the house construction industry. By analyzing previous structural failures reported in the house

construction industry, it is very clear that most of the cases have occurred when there was no professional structural designer has been consulted. Also, there is no proper analytical study which has been carried out to identify the root cause of the problem in structural failures in the house construction industry up-to-date. Therefore, it is very important to carry out proper research in order to find the major cause of house construction industry, its impact on the general public and to the society as a whole and find the solution to avoid or minimize structural failures in house construction industry in order to ensure a sustainable growth in the industry.

1.6. ARRANGEMENT OF CHAPTERS

The research report is structured in the following manner.

The first chapter discusses the basic introduction and background of the construction and house construction industry and influence of incompetent people for structural designs, research problem, problem justification, hypothesis and conceptual framework, research objectives, methodology, the significance of the research.

Chapter two consists of existing literature on the house construction industry and structural engineering practices in construction. It includes construction industry, building construction and needs of shelter, introduction to element building methods, construction industry in Sri Lanka, concept of housing and housing construction, the level of professional involvement in housing construction, structural engineering practices in construction, and structural failures of house construction and differentiate the competence and incompetence in structural construction.

Chapter three explains the research design of the study and it is an account of how the research is carried out and the methodological underpinnings that have driven the analysis.

Chapter four consists of quantitative analysis, discussion, and results of the study.

Chapter five concludes the report by understanding about the influence of incompetent people to structural designs of houses, its impact on structural failures, ways to overcome those

failures and solution to avoid or minimize structural failures in the context of the house construction industry in Sri Lanka.

CHAPTER 02

2. LITERATURE REVIEW

2.1. INTRODUCTION

This chapter provides an overview of the literature relating the house construction industry and structural engineering practices in construction. This includes the definition of the construction industry, building construction and needs of shelter, its development history, various ways of building methods in the world, introduction to element building methods, the construction industry in Sri Lanka, the concept of housing and housing construction. Further, it includes existing literature regarding the level of professional involvement in housing construction, structural engineering practices in construction, and structural failures of house construction and differentiates the competence and incompetence in structural construction.

2.2. CONSTRUCTION INDUSTRY

The construction industry is one of the fastest mounting industries around the globe. It is a branch of the commercial enterprise concerned with the construction of buildings, bridges, roads and etc. (Drewer, 1980).

Construction is derived from the Latin word *constructionem* (nominative construction). It is a derivative of 'a putting or placing together; a building'. And it means as a noun of action from past participle stem of *construere*; to pile up together, accumulate, build, make, erect. And also, the oldest sense in English goes with *construe* and leads to meaning 'the construing' (Briscoe, 1988).

Defining the construction industry itself is not straightforward; it may not be easy to come up with a universal definition. This is because of the fact that the definitions bestowed to the phrase in different societies tend to contain different aspects pertinent to that society. The definition given by the Australian Bureau of Statistics seems appropriate and widely applicable. Accordingly, the construction industry is described as including:

'all units mainly engaged in constructing buildings (including the on-site assembly and erection of prefabricated buildings), roads, railroads, aerodromes, irrigation projects, harbor or river works, gas, sewerage or stormwater drains or mains, electricity or other transmission lines or towers, pipelines, oil refineries or other specified civil engineering projects. In general, units mainly engaged in the repair of buildings or other structures are also included.... as are those engaged in the alteration or renovation of buildings, preparation of mine sites, demolition or excavation' (Hagos & Shewangzaw, 2012).

According to the Pearce Report on '*The Economic and Social Value of Construction*' (2003), there are narrow and broad definitions of the construction industry, with the narrow definition concerning itself solely to *on-site construction activity*, and the broader definition also encompasses *the quarrying of construction materials, the manufacture of building materials, the sale of the final products and associated professional services such as facilities management* (Pearce, 2003).

Ofori (1994) defines the construction industry as '*a branch of manufacture and trade based on the building, maintaining and repairing structures. This includes drilling and solid mineral exploration*'. He further explains the three categories of the construction industry. There are: *Building Construction Industry* (the construction of residential, farm, industrial, commercial and other buildings), *Heavy Construction Industry* (other than buildings, such as highways and streets, bridges, sewers, railroads, irrigation projects, flood control projects and marine construction) and *Special Trade Construction Industry* (projects such as painting, electrical work, plumbing and etc.) (Ofori, 1994).

Construction is an assembly industry (Kulatilake, 2000). It is basically segregated into two key phases like design and construction. This division is especially significant in the building process, where the two phases are mainly handled by two sets of teams. In this process, the architects and engineers are assisted by one or more consultants and produced a design for a client. Drawings are drawn in detail; specifications are given and a contractor executes the design assisted by suppliers and sub-contractors.

Construction industry development is a deliberate process (Carillo, 1994) to improve the capacity and effectiveness of the construction industry in order to meet the demand for

building and civil engineering products and to support sustained national economic and social development objectives. It promotes the increased value for money to industry clients as well as environmental responsibility in the delivery process and the viability and competitiveness of domestic construction enterprises (Ofori, 1991).

The importance of taking measures to improve the performance of the construction industry now has been recognized in several countries at various levels of socio-economic development. Dedicated agencies have been formed in many countries to administer the continuous improvement of the industry, although they have different objectives, responsibilities, and levels of authority (Ofori, 1991). In the UK, the Construction Industry Board is an industry initiative, whereas its counterpart institutions in developing countries are government agencies. They include the Construction Industry Development Board of Malaysia, the Institute of Construction Training and Development of Sri Lanka and the National Construction Council of Tanzania (Miles & Neale, 1991). Singapore's Building and Construction Authority is also a government agency (Ofori, 1991).

The construction industry everywhere faces problems and challenges (Ofori, 2000). However, in the developing countries, these difficulties and challenges are present alongside a general situation of socio-economic stress, chronic resource shortages, institutional weaknesses and a general inability to deal with the key issues. Some of the key challenges can be identified in developing countries. They are globalization, culture, and environment (Ofori, 1991).

The construction industry is one of the most significant industries that contributed to socio-economic growth, especially for developing countries. However, in the developing countries, the construction industry always faces problems and challenges, because the earth's resources are under severe due to increase in population and economic expansion (Jayalath & Gunawardhana, 2017).

The construction process is highly organized (Briscoe, 1988). It includes the manufacturers of building products and systems, the craftsmen who assemble them on the building site, the contractors who employ and coordinate the work of the craftsmen, and the consultants who specialize in such aspects as construction management, quality control, and insurance.

2.2.1. Building Construction and the Needs of Shelter

Building construction is a unique technique and it is involved in the assembly and erection of structures, primarily those used to provide shelter. It has been an aspect of life since the beginning of human existence. It is an ancient human activity that began with a purely functional need for a controlled environment to moderate the effects of climate. Today, building construction plays a significant part of industrial culture, a manifestation of its diversity and complexity and a measure of its mastery of natural forces could produce a widely varied built environment to serve the diverse needs of the society.

2.2.2. Historical Development of Building Constructions

At first, human shelters or huts were very simple and they were constructed by hand or with simple tools and perhaps lasted only a few days or months. Over time, however, even temporary structures evolved into such highly refined forms as the 'Igloo' (Oliver, 1987). Gradually more durable structures began to appear, particularly after the advent of agriculture, when people began to stay in one place for a long period of time. As cities grew during the Bronze Age, a class of professional craftsmen like bricklayers and carpenters appeared. Occasionally, slaves were used for construction work. In the 19th century, steam-powered machinery was appeared and later on diesel and electric-powered vehicles such as cranes, excavators and bulldozers appeared. Traditional construction was commenced between 4000 and 2000 BC in Ancient Egypt and Mesopotamia when humans started to abandon a nomadic existence and that was caused for the construction of permanent shelters (Hagos & Shewangzaw, 2012). Accordingly, the first shelters were dwellings, but later other functions such as food storage and ceremony were held in separate buildings.

The construction of Pyramids in Egypt (2700-2500 BC) might be considered the first instance of large structure construction. Other ancient historic constructions were Parthenon by Ictinus in Ancient Greece (447-438 BC), the Apian Way by Roman engineers (312 BC), and the Great Wall of China (220 BC). Similarly, the Romans developed civil structures throughout their empire including aqueducts, insulae, harbors, bridges, dams, and roads (Hagos & Shewangzaw, 2012).

Population growth and urbanization led to the increasing need for shelter developments and focused attention on the importance of structured building materials and techniques. Accordingly, the construction industry in many parts of the world started to grow with increasing demand. In line with this, construction companies are growing at a fast pace all over the world. With this growth of the construction industry and subsequent growth of construction companies, contractual relationships related to construction are increasing. Thus, there is a dire need for a coherent and efficient law to deal with such contractual relationships (Oliver, 1987).

According to the related literature, it could be identified that the history of the building is marked by a number of trends from time to time as;

1. The increased durability of the materials used. Earlier building materials were perishable, such as leaves, branches, and animal hides. Later more durable natural materials such as clay, stone, timber and synthetic materials such as brick, concrete, metals, and plastic were used.
2. A quest for the building of ever greater height and span; these were made possible by the development of stronger materials and by the knowledge of how materials behave and how to exploit them to greater advantage.
3. The degree of control exercised over the interior environment of building increase precise regulation of air temperature, light and sound levels, humidity, airspeed, and other factors that affect human comfort has been possible.
4. The change in energy available to the construction processes, starting with human muscle power and developing toward the powerful machinery and equipment used today.
5. The present state of building construction is complex and there is a wide range of building types, building products, and systems. The design process is highly organized and draws upon research establishments that study material properties and performance, code officials who adopt and enforce safety standards, and design professionals who determine user needs and design a building to meet those needs.

2.2.3. Development of Building Constructions

With the development of building construction as an industry, it also developed as a recognized profession. There is a number of ways of building methods in the world and they are categorized as follows and briefly described further:

1. Traditional building
2. Post-traditional (Conventional) building
3. Rationalized building
4. System building
5. Component building (Allen, 1999)

2.2.3.1. Traditional Buildings

This construction method has been developed for the use of form construction evolved by the traditional building crafts, bricklaying, carpentry, plastering, tiling, and slating. The important feature of this method is the skilled labor requirements were fairly high and nearly two-thirds of the construction work was skill craftwork.

The buildings were constructed for specific requirements, also on specific sites. Considerable amounts of fabrication as well as assembly of parts take place on-site. In this traditional building construction, the craftsmen were not only familiar with the content and order of operations in their own work or skill but most of the craftsmen carried out their work with minimum detailed information. Because of the limited range of materials and forms constructions they were aware of the other works of the construction (multi-skilled). Also, the work of the craftsmen was much more readily and inexpensive than the methods based on highly mechanized factory productions.

The traditional craft-based building method was very flexible and able to meet variations in the demand of the market. The builder operated the construction work on this basis with less expenditure, minimum losses, and fewer capital investments. This method was commonly adopted by small firms with a little capital enabled them to carry over a slack period in

demand and was reduced with the time, after the introduction of prefabricated building methods (Allen, 1999).

2.2.3.2. Post-Traditional (Conventional) Buildings

With the growth of the world, traditional building methods have always been in a state of changes from time to time with new materials and developing techniques. Most significant changes occurred with the discovery of cement and steel. New feasible forms of constructions, new materials and technologies, and long-span structures came into the field with this growth.

Post-traditional or conventional building methods were a mixture of old traditions and a new form of construction (old crafts, new materials, and techniques). New techniques of casting mass concrete at sites in formwork are similar to traditional cob and pies wall constructions.

Especially, reinforced concrete and steel was identified as pre-formed and off-site fabricating materials. Skeleton frames were introduced for prefabrication and for assembly on-site by operatives with specialized skills. But, this method was found less flexible than the traditional building method and also found labor-intensive and tied up with the mechanical plants.

Besides that, greater attention needed for planning, organization of scale of work, use of plants and equipment, systematic supply and assembly of materials and also for the whole construction process to produce specific buildings (Miles & Neale, 1991).

2.2.3.3. Rationalized Buildings

The rationalized building takes place further than post-traditional building methods, but it could be applied to constructions carried out by craft processes with traditional materials. This is the method of building in which organization techniques used in manufacturing industries and are applied to the erection processes without involving a radical change in the form of construction. The main feature of this method is the increase of the demand, size, and complexity of all type of buildings resulting in more complex construction processes which needed to economize in labor and material cost. The whole construction process is ensured with the proper flow of labor and materials through a proper organization.

Proper planning and organization and proper integration of designs and products to proceed with the construction work as a continuous process.

Design and organization are developed with a view of the continuity of operations and economy of labor. Also, more standardization methods are used to maintain the continuity in all production operations and mechanical plants as well in view of those features in this method, the productivity was high and the products were cheap (Miles & Neale, 1991).

2.2.3.4. System Buildings

System building method is mostly based on forms of construction in which the component parts of building fabric are wholly factory products and site assembled. Those components relate as parts of an integrated system of construction related to specific building types like houses, schools, factories, warehouses, etc.

Most of the system building methods are based on skeletal structures in steel, concrete or timber and load-bearing walls manufactured by pre-cast concrete panels. This includes factory produced roofs, bathroom units, room size units, garages, kitchens, etc. As the main disadvantage, those do not fit with the components of other systems of different manufacturers. It is therefore called as "Closed System" building method (Allen, 1999).

The prominent feature of this method is to reduce the number of skilled laborers to a larger extent. On the other hand, higher overheads for factory productions and higher charges for the factory to the site could be seen in this method. The economic success of this method depends on an efficient organizational system of fabrication of parts and components.

Today, most industrialized buildings often apply this method for rapid construction. On the other hand, this method is economically feasible only for large scale production with large scale market supply (Miles & Neale, 1991).

2.2.3.5. Component Buildings

Similar to the previous methods, component parts of the building fabric are wholly factory produced and site assembled in this building methods. Those components could be used

freely in conjunction with the parts of the fabric constructed on traditional lines such as brick walls, blockwork and roof tiling. This building method differs from the system building method because of the production of the components is not limited to one manufacturer and each component is interchangeable with other manufacturers‟ products. Therefore, this method is called as “Open System” building method.

Components are produced for both frame and load-bearing wall construction of different materials and all could be used separately or together to produce economic solutions to a wide range of problems. It uses interrelated factory-produced components from a variety of materials for construction.

Economic advantages of mass production may be combined with the greatest possible freedom to design to meet user and site requirements more precisely. This could be used for a wider range of building types and varieties within acceptable limits of mass production as well (Allen, 1999).

2.2.4. Introduction to Element Building Methods

System building method and the Component building method are the most recent and important construction techniques adopted at present (Miles & Neale, 1991). Both these methods are based on forms of construction in which the component parts of building fabric are wholly factory produced and site assembled. When considering the common features of both the system building and component building, all the building products of those methods are typically based on the following:

- Panels - Including ready-made walls, floors, and roofs
- Modules - Ready-made rooms, which could be pieced together to construct a whole house or flat but are used most frequently for bathrooms and/or kitchens, where all the fittings are added in the factory.

In view of the both these methods use prefabricated ‘building element’ to erect buildings, hereinafter those will be mentioned as *‘Element building methods’* in this dissertation as an umbrella term that covers the terms of *‘Modular buildings’*, *Package buildings’* as well as

'Prefabricated buildings. In fact, the use of elementary element building methods goes back to over fifty years. The end of World War II caused the modular market to truly explode and greatly evolve and all the returning soldiers came back to America looking forward to purchasing a house and start a family quickly.

This demand for homes was greater than the market place could meet and handle with the traditional building processes. This led people to look for solutions to increase efficiency and lower the cost of new house construction.

The element building processes answered both these needs. Besides, these kinds of prefabricated buildings provide the luxury of deciding upon the design and style of the buildings beforehand at the present times. It constructed using pre-fabricated components which fully equipped luxury room size capsules. When considering European and Japanese level of these elementary building methods, it can be observed that it's far beyond our domestic level. European countries like Germany have 15%, Austria has 33% and France has 5% market share. In Japan, prefabricated housing companies build more than 150,000 units per annum (Thomas & Thomas , 2012).

2.3. CONSTRUCTION INDUSTRY IN SRI LANKA

The construction industry plays a vital role in the Sri Lankan economy. The construction sector produces a wide range of products, from individual houses to major infrastructures such as roads, power plants, and petrochemical complexes, etc. New trends in Sri Lankan real estate sector are the major factor that affects the development of the construction industry in Sri Lanka. Luxury residential trends, office market trends, affordable housing trends, hospitality trends and government's mega infrastructure development projects are directly affected by the construction industry in Sri Lanka nowadays (Widanagamachchi, 2019).

With the industrial developments of the other countries of the world, most of the government and private developers in Sri Lanka are in the track of using modern building construction methods and technologies for their present construction projects. Although the conventional construction methods were embraced by all construction industries, currently it switched on

to use steel and prefabricated components (Weddikkara & Devapriya, 2000) for many construction purposes all over in the country.

A number of huge multi-story apartments, shopping complexes, factories, transport terminals, and large residential scheme projects were completed in recent times in many regions in Sri Lanka. Port City project will be the future of the construction industry of Sri Lanka and very advanced modern construction methods will be adopted for this project (www.dailynews.lk, 2019).

On the other hand, it was evident that a lot of new building methods was adopted during the construction of re-development projects on the occasion of Tsunami disaster (Weddikkara & Devapriya, 2000). However, it is observed that Sri Lanka is not in a comfortable situation to recognize and adopt new building technologies, especially for housing projects to compete with other developing countries in the world. It should be realized that at the time of Tsunami disaster, these kinds of new, low-cost and quick construction methods for dwellings and other buildings for refugees were in dire need and required within a very short period of time. But regrettably, the Central Government and Private Sector organizations were mostly unsuccessful and failed to benefit while adopting these methods (Weddikkara & Devapriya, 2000).

Therefore, performing more and more researches and developments on novel technologies and methods of the current building industry has become important and compulsory. In each and every occasion of discussions, new building methods, the time, cost, materials, technology and the economic factors have been the foremost topics (Weddikkara & Devapriya, 2000). However, in many building projects, especially in housing, we failed to recognize these important factors and turned a blind eye and ignored the social background of the user, environmental issues and the cultural influences for buildings.

Generally, a country like Sri Lanka which has outstanding precedence of cultural and social influences for buildings, especially for housing, this phenomenon should be treated as very important. Without identifying the inherent characters of those dominant factors, any attempt to discuss regarding the building construction of that context becomes a futile effort.

2.4. CONCEPT OF HOUSING

Housing is a fundamental need for civilized living in any kind of society. The provision of shelter and the steps taken by human societies to fulfill their housing needs has changed through thousands of years of history. Furthermore, the concepts of housing have been parallel to the gradual development of civilization and culture in any country and the population increase, urbanization, planning, controls and vastly the changing expectations of people produce pressure for changes in housing designs and erection methods from time to time (Henilane, 2016).

2.4.1. Main Determinant and Modifying Factors of Housing

The differences of houses are merely not as the result of physical forces which are always in harmony with its surrounding context. Based on the available literature, the following could be identified as the main determinant and modifying factors for housing in the surrounding context.

1. Climatic conditions
2. Socio-cultural settings
3. Materials, construction & technology
4. Economic conditions

Those factors are widely changed by region to region and by country to country of the world. But it is much complicated to consider the important and dominant factor for housing at the present times.

2.4.1.1. Climatic conditions

The use of characteristics of the local climate in housing is not a new innovation. Since the beginning of time, the first humans have been affected by climate and its influence on earth which compelled them to build their houses to protect themselves, especially from the weather elements. Because a house is a space where a micro-climate is created which is acceptable to inhabitants, response to climate is a vital factor within the various functions that are performed in the house.

The very first evidence of house design with climate interests in mind dates back to the fourth century B.C. Each of the region's climatic assets and liabilities could be accommodated by simple design changes such as setting, orientation, wall construction and even placement of openings.

Traditional vernacular houses in Sri Lanka are some examples of houses which were constructed with designs making use of the surrounding climate and its natural effects. Under normal circumstances, in Sri Lanka vernacular houses, verandah with eaves around the house and small windows kept the hot sun away and the interior of the house to ensure it is cool and comfortable to live in the hot climatic region (Henilane, 2016).

2.4.1.2. Socio-Cultural Settings

The socio-cultural standing in any country or a region perform as a unique feature while creating a shelter for occupant was a product of long-time experience, which embodied the traditional life patterns and environment of the particular realm. The socio-cultural factors which are unique to particular regions like organizations, religions, customs, and beliefs, attitudes, ideologies, techno-economic systems, laws, and political issues define and modify the houses form and internal space making on inhabitants. This is the main rationale for the existence of various kinds of houses with a variety of forms, shapes, materials, sizes, and colors in every nook and corner of the world.

Because of the ‘expressions’ and ‘identities’, it could be seen in different house designs, with the changes of social and cultural attitudes not only from country to country but also within the boundaries of a country. For an example, it is interesting to note that a ‘provincial identity’ in traditional housing types in Sri Lanka has been preserved even today due to the socio-cultural acceptance of those plans and forms by the inhabitants.

In some occasions, people with very different attitudes and ideologies respond to varied physical environment by their way of life parallel to the basic needs, family and the need for privacy. Those responses may vary from place to place because of changes and a difference to this phenomenon one’s own house reflects his values, aspirations and future expectations as each person’s attitudes and socio-cultural identity. For instance, when designing the

traditional Japanese houses, they as a first step begin drawing up plans for the house and determine how many 'Tatamis' mats will be needed to cover the floor. By designing different layouts, the final configuration of the mats will determine the shape and size of the house. Parallel to this, when constructing traditional houses in Sri Lanka, it was linked up with a series of rituals like *'Pada Bedeema', 'Gini Kathura', 'Poro Pada'*, etc. for shaping the plan, placement of openings, placement of the well and even placement of the toilet. That brought confidence and hope in the minds of the inhabitants on prosperity. Furthermore, this brought in a spiritual entity to the new house, religious beliefs and practices and confidence and divine blessings to the occupants in the traditional form (Henilane, 2016).

2.4.1.3. Material, construction, and technology

Materials, construction, and related technologies are generally treated as 'modifying' factors, rather than determinants because they decide neither what are to be built nor its form. Also, it could play a vital role in the type of house to be built. It could be identified that the different social and functional attributes, attitudes, and aspirations of the users are the guiding factors in the selection of building materials and methods.

There are many models that could be seen in many parts of the world in relation to this matter. In houses in the south of Island-Iceland, people use turf roofs according to the concept of 'mother nature's roof based on their legend of history. The traditional Sri Lankan tradition has been a part and parcel of nature as well as the materials were borrowed from nature and returned to nature. Most traditional houses were constructed by using materials found in the immediate vicinity using techniques developed over previous generations.

Today the world is flooded with new housing materials with vastly improved technologies. It is clear that some of the profound changes associated with the disruption of the traditional building processes and related unique concepts like the Traditional Sri Lankan house constructed using natural materials have been in the field of various building materials and their associated technologies since the industrial revolution (Henilane, 2016).

2.4.1.4. Economic conditions

Today, the economy affects as the main determining factor of personal life patterns in many social groups rather than the prefabrications new building technologies, due to the rapid industrialization and urbanization. All the socio-cultural concepts related to housing are affected inversely due to the impact of this rapid industrialization and urbanization. Consequently, the problems arise even on the beliefs, views, attitudes, and commonly in the behaviors and expectations of people.

Especially the financial capability of the people is often expected to govern the house form and character to a very great degree and such an expectation does not appear to be much valid in reality.

Most of the people migrated to urban areas which resulted in an increase in land values and individual dwelling units. This has been the main reason for the establishment of large housing schemes, modular housing, low-cost housing, multi-storied apartments, and even unauthorized housing, etc. and most of them are unable to fulfill both physical and mental satisfaction of its users (Henilane, 2016).

2.5. HOUSING CONSTRUCTION

According to the literature, house construction in Sri Lanka has an amazing historical pattern. In ancient Sri Lankan culture house was a complete non-structural building unit which has been developed using natural materials such as clay, leaves and tree branches (Marga, 1986). But with the time people have developed the concept of house construction into the more complex structure, due to the complexity of the lifestyle and the traditional concept of extended families. People needed more space and individual units or rooms have been constructed with privacy concerns. Therefore, architect elements of the building have emerged as a separate field of expertise with the time and the need (Marga, 1986).

Even though people have been concerned about the architecture and aesthetic view of the housing unit they have not specially concern the structural element of the house where it was consisting of partially or semi-structural element. Land and the space for the construction of

housing units were not limited at that time. Therefore, the concerns over the loading and stability construction elements were considered with the traditional construction practices, which have been dominated by the craftsmen who specialized for a particular section of work such as mason, carpenter, etc. They were trained and practiced the work and the knowledge passing down to their own generations. That gives the professional competency of the relevant field of work for those specialized craftsmen. People tend to believe the ability of these people to build houses by generations to generations.

When the open economy introduced to Sri Lanka, many industries have to shift the phase of its work to meet the rising demand for international trading culture. Constructions have also been accelerated rapidly. Most of the traditional practicing craftsmen had shifted their work from small scale to large scale construction project with a lot of structural elements. Then a huge number of the unskilled labor force have been developed. That workforce learned the construction norms and practices by experience. Few of them became very good practicing craftsmen at last with the experience they have gained from the large-scale construction exposure. These skilled craftsmen had challenged the status quo of the traditional housing constructions (Marga, 1986).

Land scarcity in the urban areas has been increased by the late ’90s in the Sri Lankan context. Then the people consider maximization of the land that they have. Therefore, house construction was turned into a good design and planned process (Marga, 1986). The non-structural basic unit converts into a structural construction unit (Marga, 1986). Single stories house turns into Two or more stories houses with space considerations. More structural designs have been incorporated to suit the utilization of the resources (Marga, 1986).

This transformation happened around the urban development areas in Sri Lanka. But, the cultural and socio-economical aspect of the house construction as a country does not change that much. People’s attitude toward the building a house was very much of personal work and commitment rather than a professional and planned process of work. Most of the time the scope of the architect, consultant, and even supervisory role have been conducted by the client or person who owns the house. The construction work was carried out by craftsmen who have traditional exposure or modern exposure of the large project. Both the time most

people, tend to consider the opinion of the craftsmen, with his experience, without consulting a professional, having a traditional mind-set. This will lead to a lack of the structural design aspect in the housing constructions.

Even though the professional involvement for the house construction was minimum in Sri Lanka (Jayalath & Gunawardhana, 2017), modern practice in the urban area have been changed into another way around. Professional was must to involve in the project due to the complexity of the projects.

2.6. LEVEL OF PROFESSIONAL INVOLVEMENT IN HOUSING CONSTRUCTION

Professionals which are to be involved in the Housing constructions are as follows;

- Architect
- Structural Engineer
- Construction Engineer/Technical Officer
- Quantity Survey (Allen, 1999)

This professional should have to have professional competence over the field that they have been specialized. Most of the time professional competency of the professionals who are involving in the construction in Sri Lanka was at a satisfactory level. The involvement of the professional in housing construction was at a minimum level due to the traditional practices of the craftsmen and lack of awareness of the structural Engineering practices in house construction among the common people (Kulatilake, 2000).

Professionals were highly recognized and considerably limit to a particular scale in the construction industry at the late ’90s. But with the time and the development number of professionals who practiced in the industry was increased. As well as the structural requirement for construction practices were bound by the law of the country. Urban development was controlled by government bodies like urban development authorities, provincial councils, etc. Professional have been developing their own professional bodies which declared to be the governing bodies for practicing professionals such as Institute of

Engineer Sri Lanka (IESL), Institute for Electrical and Electronics Engineer (IEEE), Sri Lanka Institute for Architect (SLIA), etc. These professional bodies have been always acting as a watchdog behind the professionals who are practicing in the field to make sure that they perform their job up to the maximum level of competency. These practices drive professionals to involve in small scale construction projects as a professional responsibility to maintain quality construction practices and environment (ICRA Lanka & IMaCA, 2011).

Even though professionals and legal bodies have been set out to get involved in the small-scale construction projects such as House construction, the major challenge which faces by the professionals in Sri Lankan context was the attitude and mentality of the Sri Lankan people. People were practice to get the craftsmen support and guidance for House construction from generations in Sri Lanka, and for the lesser cost of the attendance fee. But when it comes to the professional involvement for these types of small-scale construction will cost 3%-5% of the total project cost as an attendance fee of the professionals. Not only that but also the social level of the professionals who are practicing was considered as in the power position in the sociological context. This tends to increase the distance between professionals and the common people who want to build a personal place to live. This distance makes common people some kind of fear or mental barrier to get professionals involved in such projects. Therefore, most of the cases the house construction in Sri Lanka was still carried out by the non-professional construction personals.

Educated and Urbanized people who are most of the time practicing professionals in different fields of their own have the tendency to get the professional involvement from the beginning of the project of the house construction in Sri Lanka. That is because of the awareness of the structural practices and the concerns over the house construction in the modern world.

2.7. STRUCTURAL ENGINEERING PRACTICES IN CONSTRUCTION

2.7.1. Structural Element in House Construction

2.7.1.1. Foundation

Foundation of any construction was the most critical construction element which has to be designed with competency and proper knowledge (Papavasileiou, 2013). Design of the

foundation will mainly depend on the soil condition and land type (Load Bearing capacity), Structure of the building (load from the building). General house construction practice in Sri Lanka was done at ancient times was done considering the same factors. But it was done by selecting a good and solid soil and land, and also limiting the construction of the house at a very basic level (minimizing the load from the building). In contemporary Sri Lanka selecting such land was not a very feasible option for many. Then the space requirements have been increased and the complexity as well. That defines the structure of the house into the more complex structural building. Load from the building has also increased.

2.7.1.2. Slab

Most of the constructions carried out in the contemporary context are multi-stories building with the limitation of the land plots. The slab was acting as a load-bearing element for single flow as well as it transfers the load to beams acting as a load transferring element as well. Design of the slab has to consider the usage of the particular flow as well as the connection to the adjacent beams.

2.7.1.3. Load Transferring elements (Beams, Columns)

Beams and columns can be considered as the load transferring elements in the building which has to be designed for a particular load to be transferred through that without damaging it. Over design of the element will lead to an increase in the construction cost and under design will lead to structural failure. Optimum designs are most suitable for house constructions.

2.7.1.4. Roof

Basic roof designs are done by the carpenters in the Sri Lankan context with the practice that they have from generations. Even though the modern complex structures are required an additional structural element for the roof. Roof trusses are mostly common in any construction of the roof at present. Designs of roof trusses should also to be done to optimize the resources as well as at bearable minimum in terms of load. External factors such as wind condition, expected maximum rain intensity and additional loading to the roof such as Solar panels and any other elements have to be considered when designing the roof structure.

2.7.2. Designing and Practices

Construction of building should always follow two basic processes;

- Designing Process
- Construction Process

Designing Process of the building involve general steps of the following sequence;

- Architect gets the clients ideas and developed the architecture model of the house. Architecture model should be comprised of the building and legal regulation that have been enforcing by the authorities. That also should consider the design guidelines given by the universal recognized organization as a Code of Practises.
- Structural Engineer should get the Architectural model of the building into structural consideration. He may or may not change the column position and beam layout with the structural requirements. Structural Designer should initially consider the soil conditions to get the bearing capacity of the soil. Then the design was carried out with the foundation design and then remaining structural elements.
- Then Electrical, plumbing, and other services should be design by the qualified person.
- After all the design elements were completed, approval from the proper authorities should be taken prior to commencing the construction.

Most of the contemporary scenarios were follows in the above process with government regulation and legal enforcement. But after approvals have been taken from the authorities, people concern only the matters regarding the construction process. In most of the cases, the design of the structural Engineer was not considered properly as it occurs more cost than the method suggests by the contractor who was incompetence in structural designs. But people do not have the awareness of the real conditions of the structural requirement of the building.

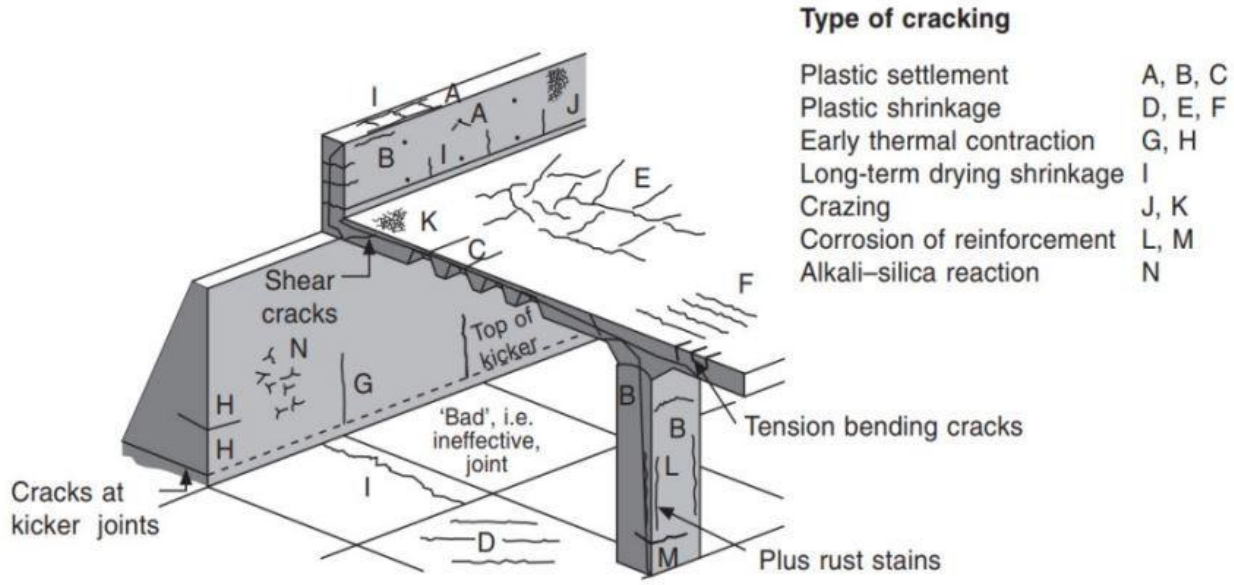
2.8. STRUCTURAL FAILURES OF HOUSE CONSTRUCTION

2.8.1. Definition of Structural Failure

Structural failure begins to occur when the material is stressed to its upper strength limit causing to rupture or extreme deformations. The ultimate strength of the material or the system is the limit of the load-bearing capacity. On reaching this limit, the construction materials could already be damaged, and their load carrying capacity is suddenly decreased permanently. If the system is properly designed, a local collapse should normally not be a cause of instant or gradual failure of the complete building. The ultimate failure strength of the construction elements should be carefully considered in the design of structures to prevent failure. (Almarwae, 2017)

The broad definition of structural failure may have a different aspect in terms of small-scale constructions. A simple crack in the wall or floor will imply the failure in the structure in some aspect. It may not be directly a structural failure where materials cannot bear the loads and reaching the limits of their strengths, but those types of circumstances may lead to a showcase of a structural issue in the building.

There are different types of cracks that can be identified in a structural building. Each type of crack will differentiate the type of failure in the structure. Cause of failure and corrective measures that have to be taken for each type of cracks are varied. Illustration of the crack types can be as follows;



2.8.2. Consequences of Structural Failures

The consequences of structural failures typically come in several forms. For example; fatalities, injuries, structural damage, damage to contents, loss of functionality and environmental damage. When considering structural failures, these consequences are often divided into two categories, direct and indirect consequences.

- **Direct consequences** are those resulting from damage states of individual components. Generally, direct consequences are confined to the effects of immediate damage following the occurrence of a hazard and are related to the vulnerability of the structure.

- **Indirect consequences** are related to a loss of system functionality and failures, as a result of local failures, and are related to the robustness of the structure. Indirect consequences occur as a result of direct consequences (Janssens, O'Dwyer, & Chryssanthopoulos, 2015).

2.9. DIFFERENTIATE THE COMPETENCY AND INCOMPETENCY IN STRUCTURAL CONSTRUCTION

The research and studies done to identify the definition of "competence" of Engineer has been concluding that the competency of an Engineer was not only measured by the Engineering practice, knowledge and capability, but also should have wide knowledge over the common practices as well as other related areas such as political, environmental, sociological, etc. (Eknayake, 2017) Therefore, the Competency of an engineer was defined in both technical and non-technical competency.

"While taking various explanations and definitions about competence into account, measurable dimensions of technical competences were derived from the studies of OECD (OECD, 2009) and Nguyen (Nguyen, 1998). They are; Competence and updated knowledge in computer science and technology, Competence in mathematics skills and problem-solving skills, Competence in Engineering & Science fundamentals Competence in Engineering Practice, Competence in invention and development of new products/solutions.

Similarly, the measurable dimensions of nontechnical competencies were derived from the study of Heuristic Model of Engineering Nontechnical Competences (Teichmann, 2013) and those are; Professional ethics, Personal competences Interpersonal competencies, Leadership, management, and administrative competences, Innovation and entrepreneurial competencies and Law and legal system competences (Eknayake, 2017).

Professional does not make them self as competent in a particular field if they do not possess the above-mentioned capacity updated with them. Therefore, general practicing craftsmen such as masons, carpenters, subcontractors cannot claim them self as a qualified or competent person to undertake structural designing work in a responsible manner.

Experience can make some people experts in the work that they are doing, but the competency level of the particular practice cannot gain only with experience. It requires much more than that. Therefore, we can define Incompetency in the Structural design as a person's inability to make a correct judgment with the existing condition using knowledge and experience based on the scientific and engineering background (Eknayake, 2017).

CHAPTER 03

3. RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter is consisting of the methodology adopted in addressing the influence of incompetent people to structural designs of houses, its impact on structural failures and ways to overcome in the context of the house construction industry. The chapter begins with the research design, study area, and sampling strategies and sample size of the study. Then, it discusses how the fieldwork was conducted, which included the distribution of questionnaires. The written transcripts of the questionnaire survey are provided. Finally, data analyzing strategies are discussed at the end of the chapter.

3.2. RESEARCH DESIGN

This research has to be designed under the explanatory research design. Since it is totally based on the quantitative method, the explanatory research design is used. And also, as a study of hypothesis testing, the explanatory research design is selected as the most applicable research design for the research.

3.3. STUDY AREA

The population of this research was all the activities involved parties or responsible persons of the housing construction project such as clients, labors and engineers. Housing construction projects in Western Province was selected as the study area of the research. This is because, most of the situations, the client does not obtain services of professional structural designers and engineers in designing works involved in the house construction in the Western province in terms of volume compared to other areas. Also in this province most of outsiders from all over the island have come for seeking employment opportunities, later settle in the area possessing an own house. Researchers' secondary data revealed that these settled peoples' influence to the housing construction industry is immense especially, due to their need of own house verses financial constraints. Accordingly, it was facilitated to build up a

comprehensive comparison of the difference between the influence of incompetent people and the professionals to structural designs of housing construction

3.4. SAMPLING

The Purposive and Snowball Sampling methods are used in this study under the Non-Probability sampling method for selecting key respondents such as clients, engineers, and labors. Accordingly, it was distributed a sample of 30 clients, 30 engineers, and 30 labors.

3.5. SOURCE OF DATA

This study is based on both primary and secondary information pertaining to the study area. The primary data was collected from selected clients, labors and professional engineers. Secondary data was collected using previous reports and magazines, published books and internet sources.

3.6. DATA COLLECTION

This study was totally based on quantitative data. As such, in this study, the method utilized for data collection was a quantitative method. For the purpose of collecting primary data, Structured Questionnaire Survey was used. It was conducted with selected clients, labors (both masons and carpenters) and professional engineers.

3.6.1. Quantitative Methods

The aim of this research is to find out the influence of incompetent people to structural designs of houses and to optimize the solutions to avoid or minimize structural failures from the intervention of the incompetent people. In order to identify the relations among variables related to housing construction and structural design strategies, quantitative methods were used. As Creswell stated through the quantitative research methods would be easier to specify how and why variables and relational statements are interrelated (Creswell, 2009). Accordingly, the analysis of quantitative data is mainly in the form of percentage analysis. The analysis is supplemented by graphs and charts.

Structured Questionnaire Survey was used as a quantitative tool to collect data regarding the influence of incompetent people to structural designs of houses.

3.6.1.1. Questionnaire Survey

Questionnaires are relatively one of the easiest and economical quantitative tools to reach a large number of respondents. Bartusch and Pham stated that questionnaires are practical means of gathering data as the relevant respondents could be managed the way the researcher wants (Bertsch & Pham, 2012). And unlike other primary data collection tools, the respondents do not feel pressurized in responding as they will take their own time to respond freely (Creswell, 2009).

Accordingly, three types of questionnaires were developed such as clients based (Annex 1), labors based (both masons and carpenters) (Annex 2) and professional engineers based (Annex 3). It was decided to distribute a sample of 30 clients, 30 labors and 30 Engineers. The questionnaire was designed in a structured manner to test the hypothesis set above in order to analyze the validation of them.

The use of questionnaires helped to gather the relevant data in an easier way for the huge sample and from the various levels of people. However, there were differences in interpreting and understanding certain questions by respondents that acted as a barrier to gather accurate data.

3.7. DATA ANALYSIS

The quantitative analyzing method was used for the data analysis in this study. After data collection, data were tabulated using the data matrix and by assigning a weight to the Likert scale in the relevant fields of the matrix. When assigning a weight to the Likert scale there must be a rationale appropriate to the question and answers in order to reflect their attributes properly applicable to the hypothesis that is to be tested. Accordingly, the data and information which were obtained from the different sources were processed using the SPSS software package. Percentage analysis was used to analyze the responses and developed relevant graphs and charts to further clarify the findings. Similarly, frequency tables, simple

percentage, and descriptive statistics were also used. Finally, relevant theories and finalized data were synthesized to reveal the findings through this research.

CHAPTER 04

4. DATA ANALYSIS

4.1. INTRODUCTION

This section described the in-depth analysis of data collected for primary and secondary data gathered from the clients, Engineers, and labors who are involved in small scale constructions. The section included a comparison of variables and their attributes, validation of hypothesis, how strongly related each variable to the dependent variable, etc.

Prior to executing tabulation and data analysis for the questionnaire survey, each answer of questions was assigned a weight from 1 – 5 Likert Scale considering the impact to a particular area of importance. This conversion is useful when executing in-depth analysis such as correlation and regressions.

4.2. ANALYSIS OF SECONDARY DATA

The data have been collected from the experts and engineers in the small-scale construction industry. They have been often observing this structural issue in the field. The following table shows the representation of the data provided by the experts in the industry.

Table 2: Types of structural Failures in the field

Type of Structural Failure	High impact		Low impact		Total
Cracks	22	36%	21	34%	43
Settlement	8	13%	3	5%	11
Deformations	3	5%	4	7%	7
Total	33	54%	28	46%	61

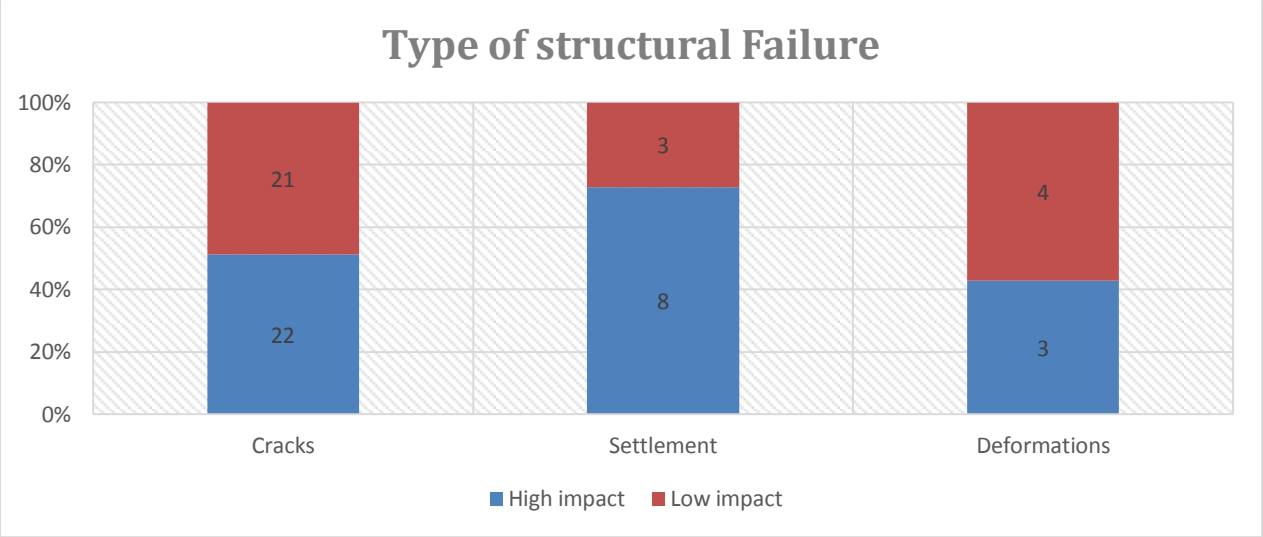


Figure 2: Types of structural failures and impact level

The above data shows that the structural failures in the house constructions can have both high and low impact, whereas 54% of the failures gives a high impact for the construction. The professional qualifies person involved in the above failures can be provided as follows;

Table 3: Involvement of competent people vs structural failure

Type of Structural Failure	Cracks		Settlement		Deformations	
	High	Low	High	Low	High	Low
Involving competent people	7	5	1	1	0	1
Not Involving competent people	15	16	7	2	3	3
	22	21	8	3	3	4

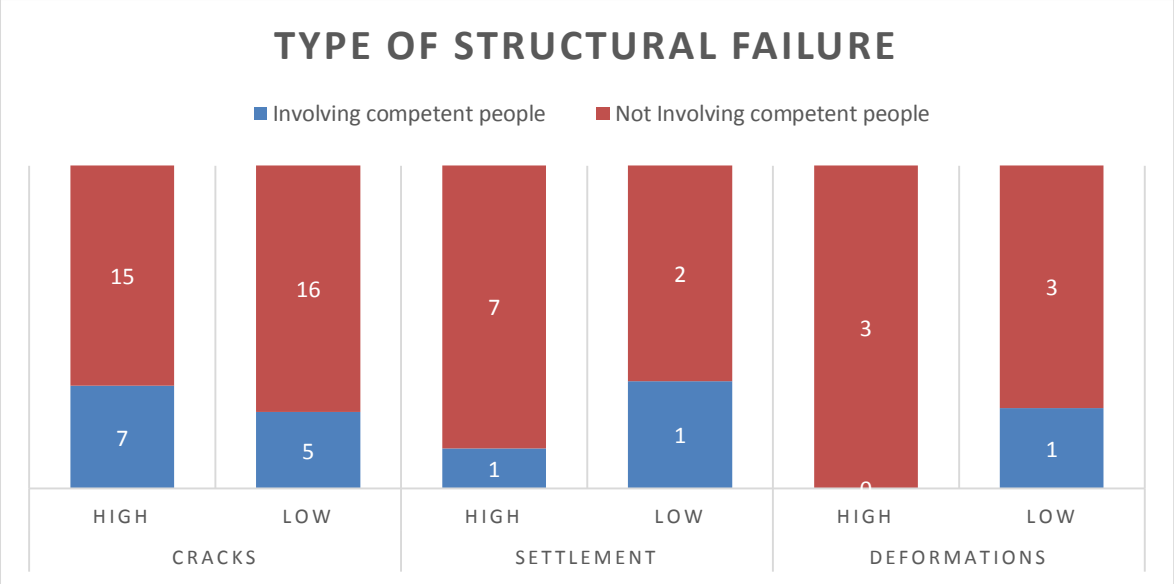


Figure 3: Involvement of competent people vs structural failure

The above representation will clearly indicate that 75% of the failures happened in the constructions which competent people are not involved, but it was controlled to 25% by the professionally qualified people who are involved in the projects. Therefore, we have a clear implication to continue the research to find out the real situation behind this result and interpret that in terms of the house construction projects.

4.3. ANALYSIS OF RESPONSES TO THE QUESTIONNAIRE

Responses received to the questionnaire have been categorized by their experience in the industry. The qualitative analysis distinguishes insight of data collected in terms of reliability of data and their quality.

Table 4: Overall Experience of the respondent

Overall Experience	Labour		Engineer	
	Responses	Percentage	Responses	Percentage
Less than 3 year	2	6.67%	22	73.33%
3 - 6 years	8	26.67%	8	26.67%

7 - 10 years	14	46.67%	0	0.00%
10 - 15 years	4	13.33%	0	0.00%
More than 15 years	2	6.67%	0	0.00%
Total	30	100%	30	100%

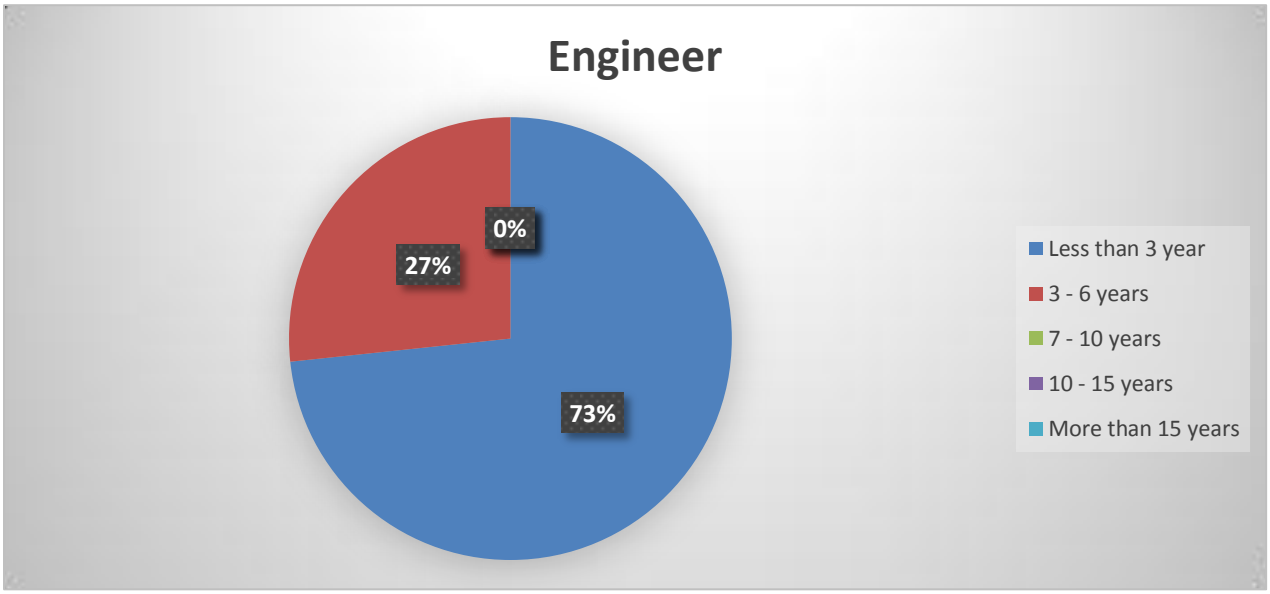


Figure 4: Experience of responded Engineers

The above data representation shows that most of the Engineers who respond were the professionals who have less experience. Rather we can comment that as the greatest number of Engineers who are involved in the house construction do not have a higher level of experience in the field. If they have higher experience, they will try to focus on large scale project rather than house construction.

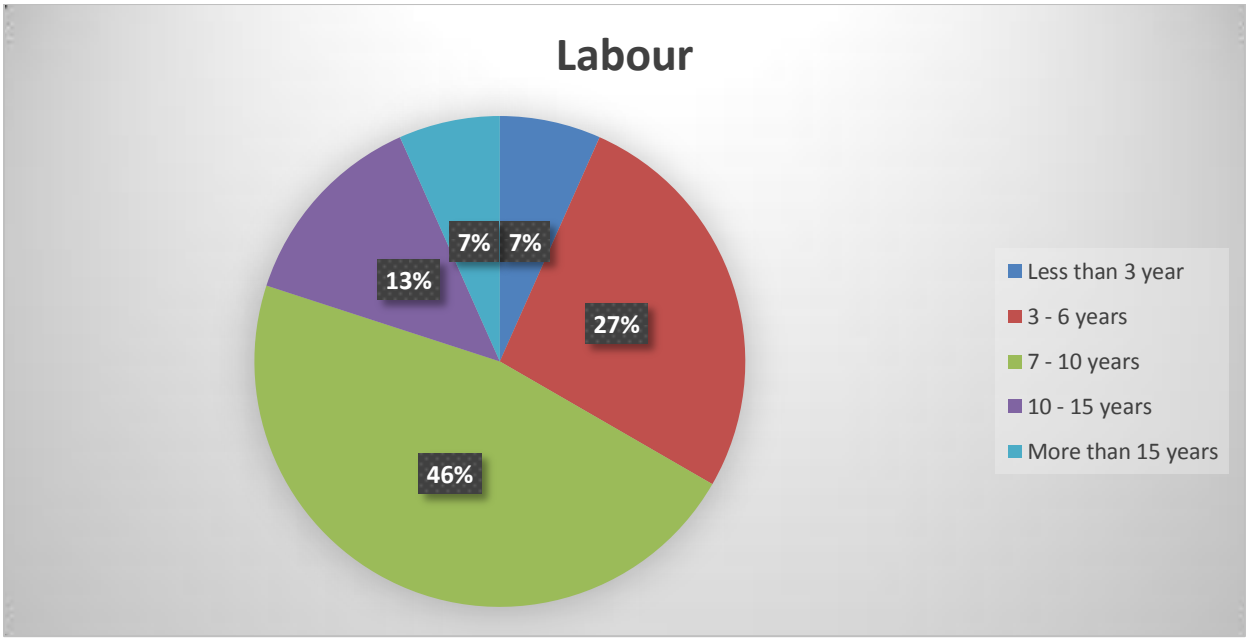


Figure 5: Experience of responded labors

It is rather opposite was for the labors who are involving in the housing project. More than 50% of the respondents have more than 7year of experience in the field. That will lead to over experience of the labor in the particular field than the engineers.

The clients who respond to the questionnaire were people whose first experience of building a house. Most of the time it was the case in the real world.

4.4. Priority Base Analysis of Contribution Factors for Structural Failures in the house constructions

The researcher hypothesized there are four key factors contribute Structural failures in House Construction projects such as Client's Lack of knowledge, Labors lack knowledge and manipulations seeking advantages, Engineers Lack knowledge and experience, Engineer's lack of confidence and communication skills. Above hypothesis can be tested in a qualitative manner using data collected from industry expert through the questionnaire.

4.4.1. Structural failures are due to Clients lack of knowledge and misunderstandings

Table 5: Structural failure due to client's lack of knowledge and misunderstanding

	Labor respond			Engineer respond			Client respond				
	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3	Avg	%
First Priority	6	10	18	18	6	20	24	18	4	6.89	46%
Second Priority	14	8	8	10	4	6	6	10	6	4.00	27%
Third Priority	4	4	2	2	10	4	0	2	6	1.89	13%
Fourth Priority	2	4	2	0	8	0	0	0	10	1.44	10%
Fifth Priority	4	4	0	0	2	0	0	0	4	0.78	5%
										15.00	100%

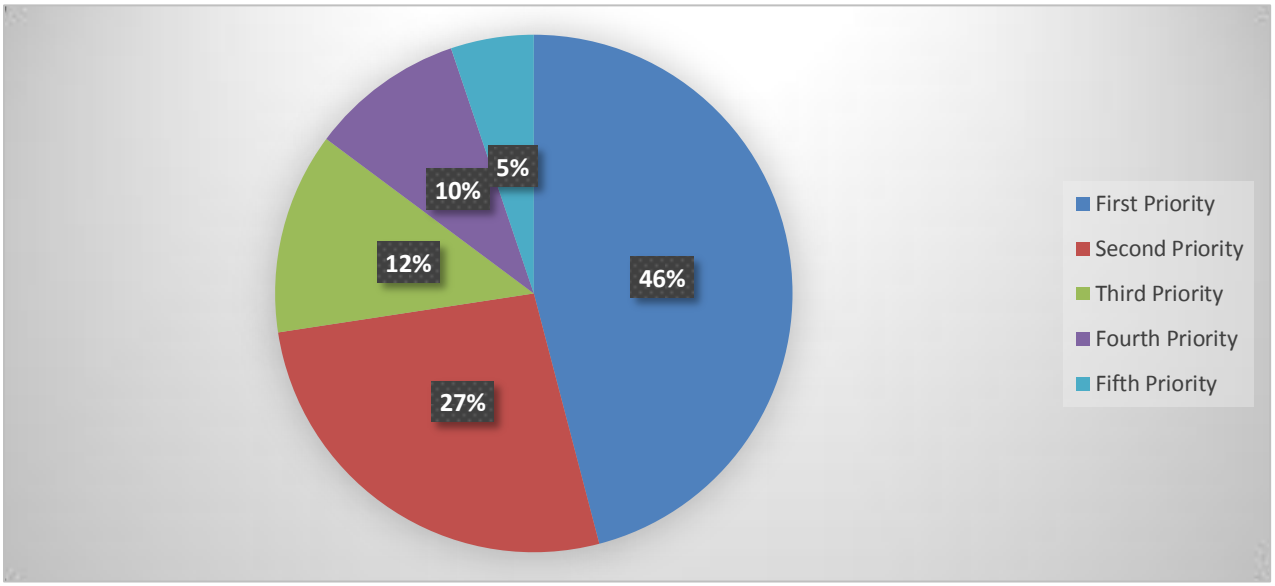


Figure 6: Structural failure due to client's lack of knowledge and misunderstanding

The above figures show that the majority have placed their priority in terms of the client's lack of knowledge and misunderstanding criteria questions as first and second. That implies that clients have some kind of awareness to get the structural details from the engineers even

though they don't possess the required level of understanding. But it also emphasizes that clients have made variations to the original scope of the project without getting proper structural concerns.

4.4.2. Structural failures are due to Labors lack of knowledge and manipulations seeking advantages

Table 6: Structural failures are due to Labors lack of knowledge and manipulations seeking advantages

	Labor respond			Engineer respond		Client respond				
	Q1	Q2	Q3	Q1	Q2	Q1	Q2	Q3	Avg	%
First Priority	12	6	4	10	6	6	6	6	7.0	23%
Second Priority	14	10	8	14	12	12	12	14	12.00	40%
Third Priority	2	12	12	4	10	8	10	10	8.5	28%
Fourth Priority	2	2	4	2	2	4	2	0	2.26	8%
Fifth Priority	0	0	2	0	0	0	0	0	0.26	1%
									30.00	100%

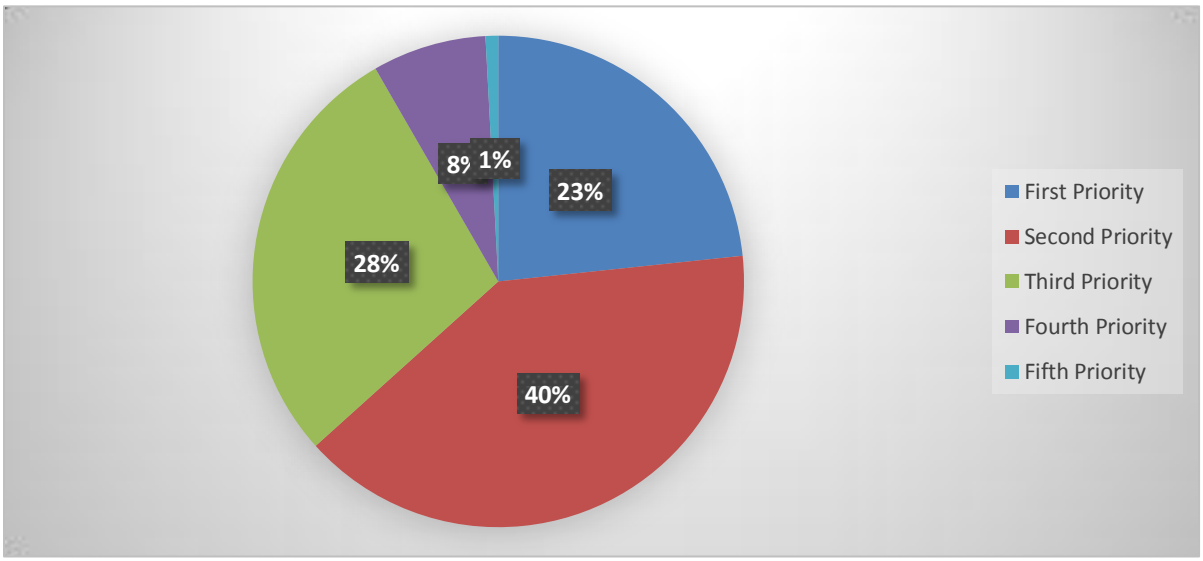


Figure 7: Structural failures are due to Labors lack of knowledge and manipulations seeking advantages

The above representation of data shows that the majority have been considering the second priority for this option. Where it implies that lack of knowledge of the labors and manipulations seeking advantage was mostly possible in the practical world where more than 60% of the respondent agreed with the statement.

4.4.3. Structural failures are due to Engineers lack of knowledge and experience

Table 7: Structural failures are due to Engineers lack of knowledge and experience

	Labor respond		Engineer respond			Client respond			
	Q1	Q2	Q1	Q2	Q3	Q1	Q2	Avg	%
First Priority	4	6	6	2	4	2	4	4.00	13%
Second Priority	6	10	6	4	10	6	8	7.12	24%
Third Priority	12	8	10	10	10	12	12	10.48	35%
Fourth Priority	6	4	6	8	6	10	6	6.48	22%
Fifth Priority	2	2	2	6	0	0	0	1.72	6%
								30.00	100%

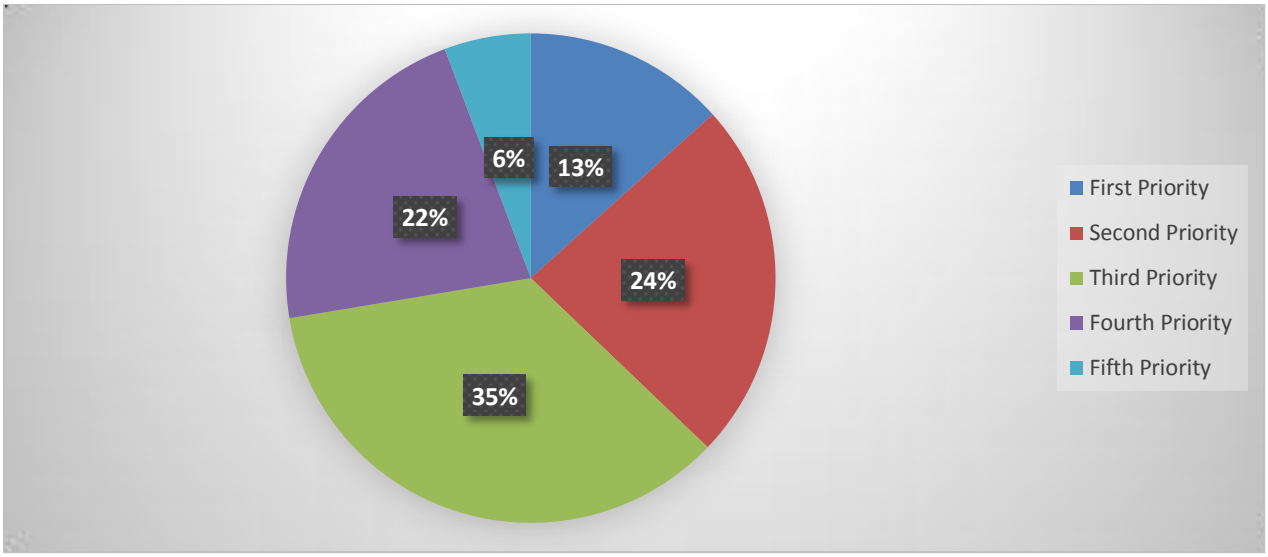


Figure 8: Structural failures are due to Engineers lack of knowledge and experience

This table and chart represent the data which implies that the knowledge and the experience that the Engineers have in the field are sufficient enough not to drive the construction into structural failure. But almost 40% of the responses show that most of the time Engineers are not having sufficient level of experience and knowledge to be competent with the requirement.

4.4.4. Structural failures are due to Engineers lack of confidence and communication skills

Table 8: Structural failures are due to Engineers lack of confidence and communication skills

	Labor respond		Engineer respond		Client respond			
	Q1	Q2	Q1	Q2	Q1	Q2	Avg	%
First Priority	4	12	10	12	4	14	9.34	31%
Second Priority	6	10	8	12	12	10	9.66	32%
Third Priority	10	8	12	4	10	2	7.66	26%
Fourth Priority	8	0	0	0	4	0	2.00	7%
Fifth Priority	2	0	0	2	0	4	1.34	4%
							30.00	100%

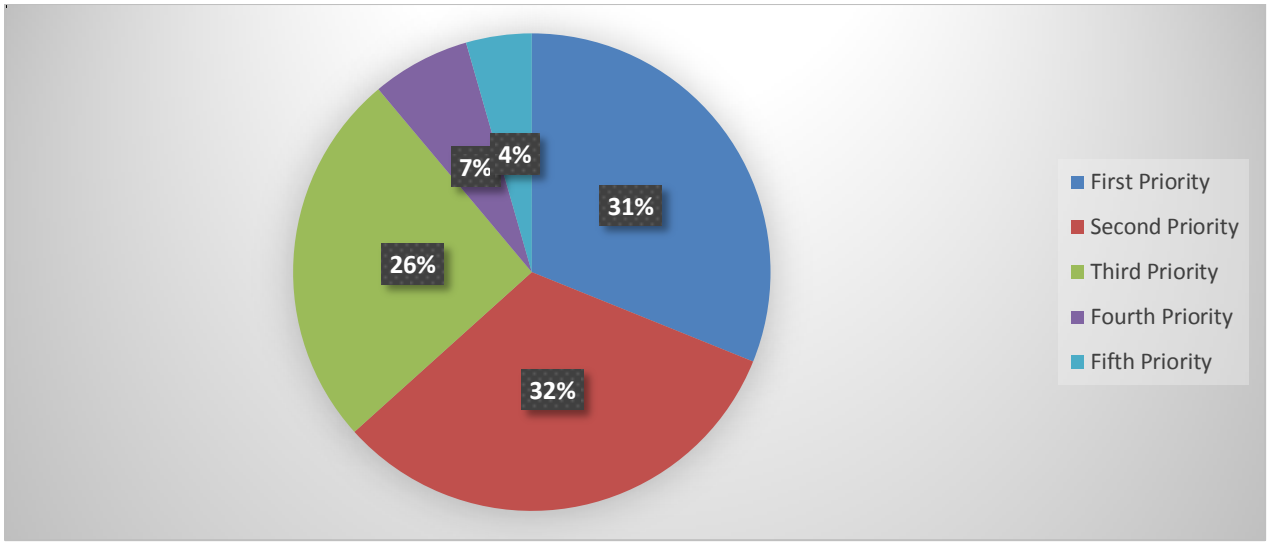


Figure 9: Structural failures are due to Engineers lack of confidence and communication skills

More than 60% of the responses imply that the Engineers communication skills and the confident level in the housing construction are not up to the required level. That will be the leading factor for structural failure where the communication gap between Engineers and the clients as well as the labors will create misunderstanding about the real structural requirement.

4.4.5. Comparison of the hypothesis developed

Table 9: Comparison between hypothesis

	Client's lack of knowledge and misunderstandings	Labor's lack of knowledge and manipulations seeking advantages	Engineers lack knowledge and experience	Engineers lack confidence and communication
First Priority	46%	23%	13%	31%
Second Priority	27%	40%	24%	32%
Third Priority	13%	28%	35%	26%
Fourth Priority	10%	8%	22%	7%
Fifth Priority	5%	1%	6%	4%
	100%	100%	100%	100%

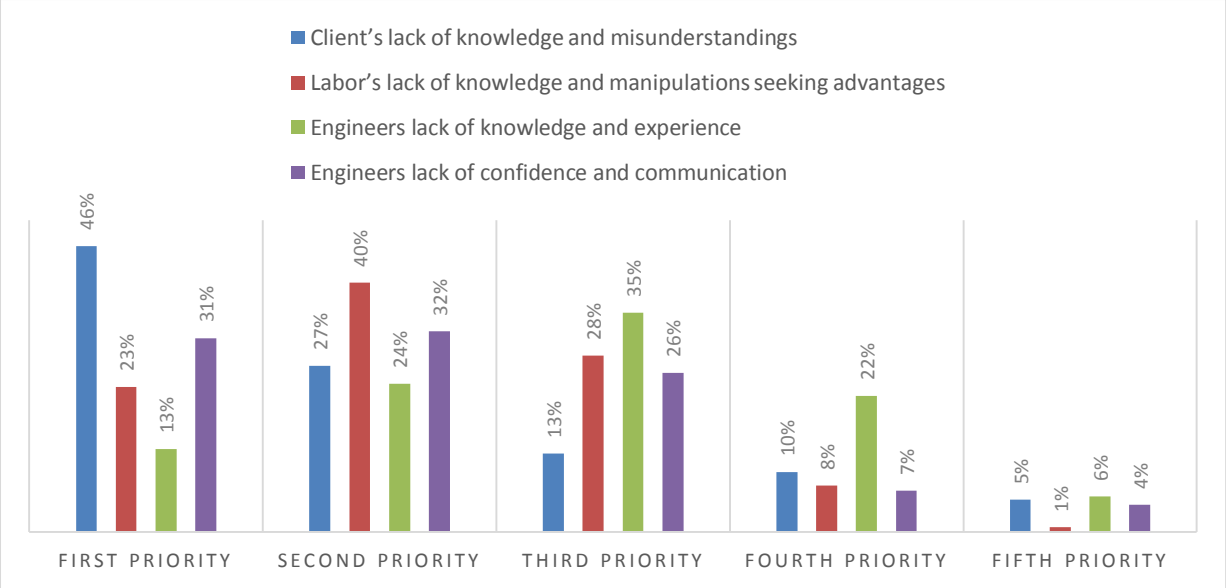


Figure 10: Comparison between hypothesis

4.5. Validation of Hypothesis

Regression analysis and correlation analysis methodology were used for validating hypothesis. Pearson correlation coefficient derives the relationship among tested variables and their strength of association. Pearson correlation coefficient always generates a value between +1 and -1. If the coefficient is positive it assumes the association is positively related to testing variables, or if the coefficient generates negative value it suggested association is negatively related to testing variables. If the value is more than 0.5 it suggested a strong relationship among testing variables either positively or negatively. If the value is zero (or closer to zero) suggested there is no relationship among testing variables.

Significance value gives the probability of the relationship generated by Pearson correlation that could happen. If the significance value is less than the defined value of 0.05 or closer to zero means there is a higher probability that the generated correlation could happen and referred as correlation is statistically significant or in other words correlation is reliable.

4.5.1. Structural failures are due to Clients lack of knowledge and misunderstandings

H1	H1a; Structural failures are due to Clients lack of knowledge and misunderstandings
	H1o; Structural failures are not due to Clients lack of knowledge and misunderstandings

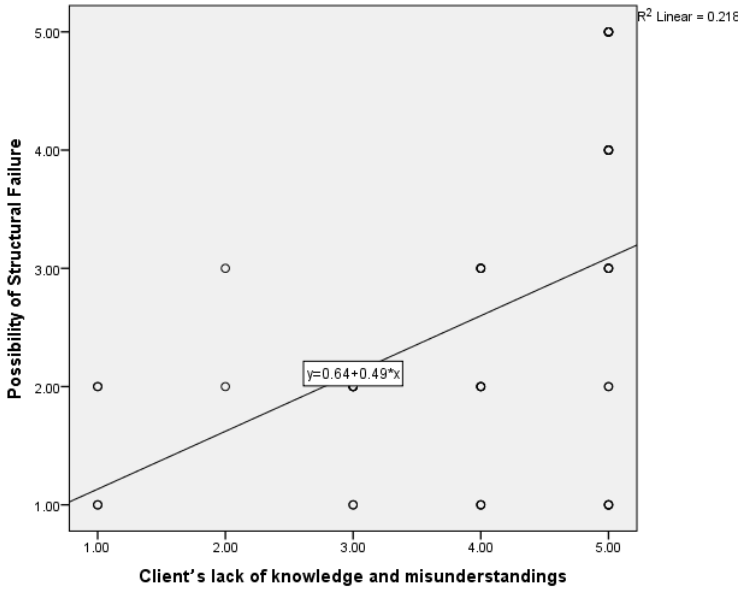


Figure 11: Regression of lack of client's structural knowledge and structural failure

Table 10: Correlation for lack of client's structural knowledge and structural failure

Correlations

		Possibility of Structural Failure	Client's lack of knowledge and misunderstandings
Possibility of Structural Failure	Pearson Correlation	1	.466**
	Sig. (2-tailed)		.001
	N	45	45
Client's lack of knowledge and misunderstandings	Pearson Correlation	.466**	1
	Sig. (2-tailed)	.001	
	N	45	45

**. Correlation is significant at the 0.01 level (2-tailed).

For the above two parameters, the Pearson Correlation coefficient has derived as a positive value (0.466). Therefore, the null hypothesis is rejected and alternative hypothesis is accepted. Also, the value (0.466) is very closer to the 0.5 but below 0.5, which means that the relationship between the two parameters is not strong. The significance of the correlation is 0.001 which is lower than the defined significance level (<0.01).

Consequently, it can be concluded that Structural failures in the house construction and the client's lack of knowledge and misunderstanding have a positive relationship. However, the correlation is not very strong.

4.5.2. Structural failures are due to Labors lack of knowledge and manipulations seeking advantages

H2	H2a; Structural failures are due to Labors lack of knowledge and manipulations seeking advantages
	H2o; Structural failures are not due to Labors lack of knowledge and manipulations seeking advantages

Table 11: Correlation for Structural failures and Labors lack of knowledge and manipulations seeking advantages

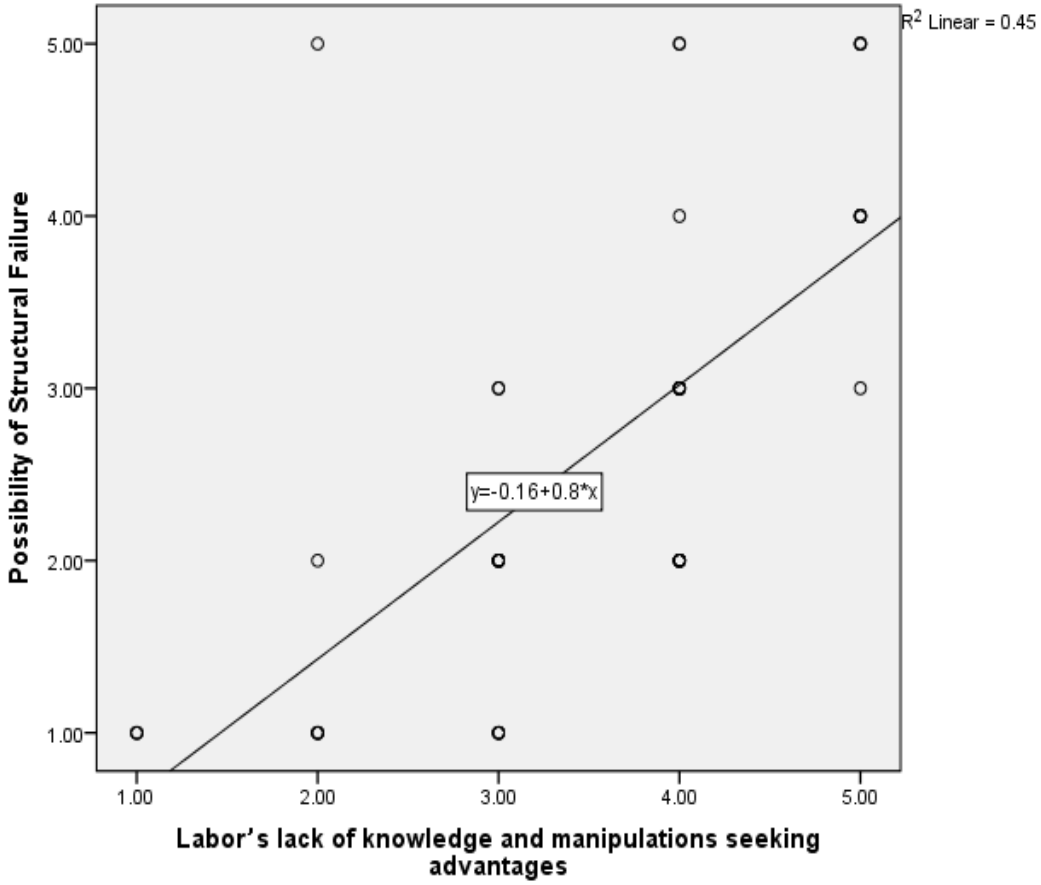


Figure 12:Regression of Structural failures and Labors lack of knowledge and manipulations seeking advantages

Correlations

		Possibility of Structural Failure	Labor's lack of knowledge and manipulations seeking advantages
Possibility of Structural Failure	Pearson Correlation	1	.677**
	Sig. (2-tailed)		.000
	N	45	45
Labor's lack of knowledge and manipulations seeking advantages	Pearson Correlation	.677**	1
	Sig. (2-tailed)	.000	
	N	45	45

**. Correlation is significant at the 0.01 level (2-tailed).

For the above two parameters, the Pearson Correlation coefficient has derived as a positive value (0.677). Therefore, the null hypothesis is rejected and the alternative hypothesis is accepted. Also, the value (0.677) is close to the 0.5 but above 0.5, which means that the relationship between the two parameters is considerably strong. The significance of the correlation is 0.000 which is lower than the defined significance level (<0.01).

Consequently, it can be concluded that Structural failures in the house construction and Labors lack of knowledge and manipulations seeking advantages have a strong positive relationship. Also the correlation is strong.

4.5.3. Structural failures are due to Engineers lack of knowledge and experience

H3	H3a; Structural failures are due to Engineers lack of knowledge and experience
	H3o; Structural failures are not due to Engineers lack of knowledge experience

Table 12: Correlation of Structural failures and Engineers lack of knowledge and experience

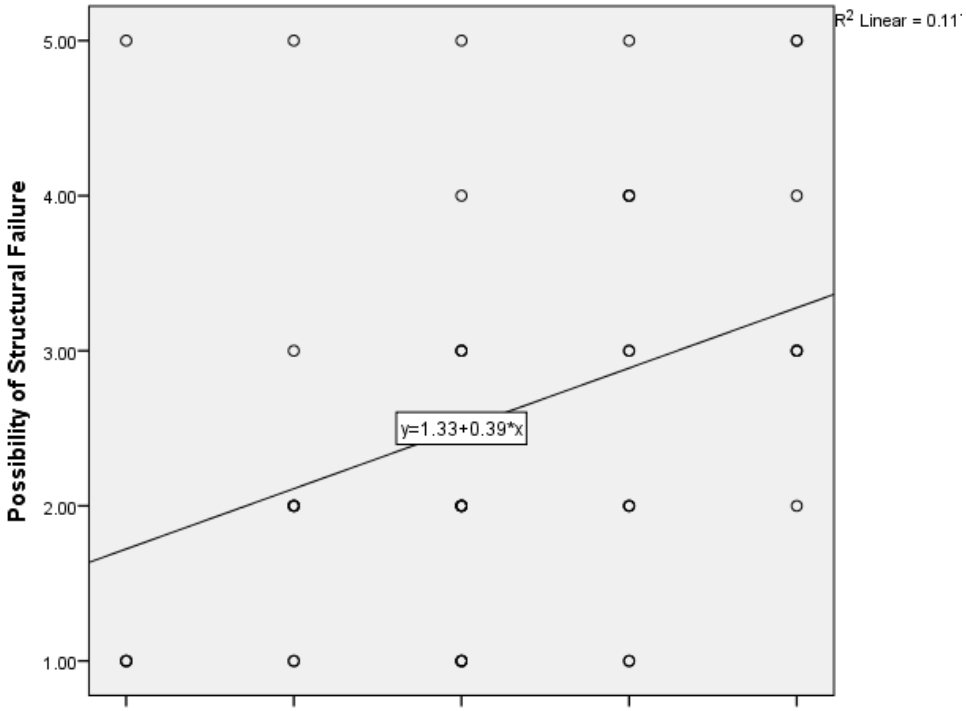


Figure 13: Regression of Structural failures and Engineers lack of knowledge and experience

Correlations

		Possibility of Structural Failure	Engineers lack knowledge and experience
Possibility of Structural Failure	Pearson Correlation	1	.342*
	Sig. (2-tailed)		.021
	N	45	45
Engineers lack knowledge and experience	Pearson Correlation	.342*	1
	Sig. (2-tailed)	.021	
	N	45	45

*. Correlation is significant at the 0.05 level (2-tailed).

For the above two parameters, the Pearson Correlation coefficient has derived as a positive value (0.342). Therefore, the null hypothesis is rejected and the alternative hypothesis is accepted. Also, the value (0.342) is closer to the 0.5 but below 0.5, which means that the relationship between the two parameters is not strong. The significance of the correlation is 0.021 which is lower than the defined significance level (<0.05).

Consequently, it can be concluded that Structural failures in the house construction and Engineers lack of knowledge and experience have a positive relationship. However, the correlation is not very strong.

4.5.4. Structural failures are due to Engineers lack of confidence and communication skills

H4	H4a; Structural failures are due to Engineers lack confidence and communication skills
	H4o; Structural failures are not due to Engineers lack confidence and communication skills

Table 13: Correlation of Structural failures and Engineers lack of confidence and communication skills

Correlations

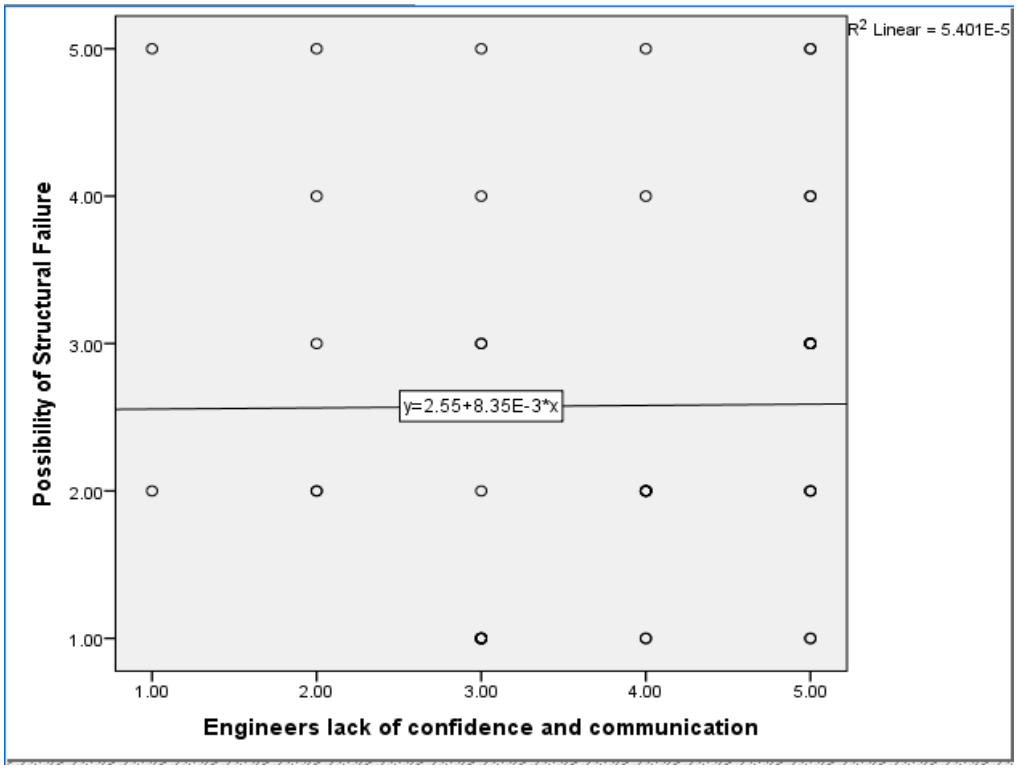


Figure 14: Regression of Structural failures and Engineers lack of confidence and communication skills

		Possibility of Structural Failure	Engineers lack confidence and communication
Possibility of Structural Failure	Pearson Correlation	1	.01
	Sig. (2-tailed)		.962
	N	45	45
Engineers lack confidence and communication	Pearson Correlation	.01	1
	Sig. (2-tailed)	.962	
	N	45	45

For the above two parameters, the Pearson Correlation coefficient has derived as a positive value (0.01). But it was closer to Zero (0.000). Therefore, we cannot reject the null hypothesis where the alternative was in favour. Then we cannot come to conclude that there was no relationship between Structural failures and the Engineers lack of confidence and communication.

We can conclude that the relationship between the above two factors are considerably lower than the other factors than we discussed earlier.

CHAPTER 05

5. CONCLUSION AND RECOMMENDATION

Secondary data collection from the stakeholders in a house construction project has been considered for this research to analyze the research question. Structural failures in the house constructions have been identified by the expert's opinion and the literature review. The hypothesis has been developed base on the above finding of the research and then the previous chapter was about the detail data analysis and validation with respect to the developed hypothesis on four factors which affect to the structural failures in house constructions namely Clients lack knowledge and misunderstandings, Labors lack knowledge and manipulations seeking advantages, Engineers lack of knowledge and experience, Engineers lack of confidence and communication skills. This chapter focuses on the conclusion of the finding from the previous chapters and recommended mitigation measures that can suggest accordingly.

5.1. Factors Affecting Structural failures in house constructions

5.1.1. Clients lack of knowledge and misunderstandings

According to Table 05 and figure 06 we can observe that most of the respondents have given their priority respond as a structural failure will occur due to the lack of knowledge and misunderstanding that client has about the structural practices. More than 70% of the responses are in favor of the above statement. Not only that but also according to the regression analysis (Figure 11) and the Pearson Correlation analysis (Table 10) we can validate the hypothesis of Structural failures of the hose constructions are due to the Clients lack knowledge and misunderstandings.

Most of the time clients experiencing this house construction for the first time in their life. They do not have the proper understanding or even a clear mindset about the process of house construction. There are no guiding units for this purpose as well. Therefore, they tend to make the decision based on the unknown sources which may be unreliable due to many

reasons. What so ever they do not have proper informal guidance to follow when it comes to house construction.

But there are many Professional Engineers and Engineering companies are there in the construction industry focusing on small scale construction project in this nature. They have the capacity and the capability of addressing these issues of the client very well. The common contradiction between these two was that the cost margins that these company is having are really high compared to the non-competent labor or a contractor. Therefore, clients are not tended to get proper mentoring and structural guidance from the experts. They will go for the least cost option unknowingly allowing structural failures into the house construction due to lack of expert's involvement.

Awareness and proper guidance event from the industry itself can mitigate this condition that will drive the construction industry to the unsatisfactory level for the customers and clients.

5.1.2. Labors lack knowledge and manipulations seeking advantages

According to the detail data analysis and the validation done in the previous chapter, we can conclude that there has been a comparatively stronger relationship between the structural failure and the labors lack of knowledge and manipulations seeking advantages. This has been clearly implying from the priority responses as well. The strong relationship suggests that the labors are the ones who dominate the house construction markets in contemporary Sri Lanka. Most importantly the structural concerns are also amended by the labors as per their convenient in the construction.

This pattern can be clearly due to traditional house construction practices in Sri Lanka. But at in the present context, it is not the proper practice to continue as structural building elements have been incorporated to the house constructions. Labors have the capacity to absorbed common structural practices done by the structural Engineers in the constructions but all the structural practices are depending on the particular situation, and it will vary with the situations. Therefore, practicing a general or common practice will not guarantee the structural competency of the building.

Most of the labors who have been practicing in the house constructions are tend to have more experience than the professional engineers in the same. Therefore, they seek to misuse the advantage that they are having vast experience. Experience can build their skill level to a certain standard as a labor, but not the structural designing knowledge perspective. Therefore, the labors should also practice only at their capacity to retain the goodwill of the construction industry among the people.

5.1.3. Engineers lack knowledge and experience

Figure 13 and Table 13 will show the relationship between the structural failure and the Engineers lack knowledge and experience, which have concluded that there is a positive relationship and it was not very strong as the relationship between the structural failure and the Lack of knowledge of the labors. This can also be identified in the priority responses as well in figure 8 and table 7.

Most of the Engineers who have been responded to this research have less experience level in the construction industry compare to the labors in the same. Where they have been practicing the theoretical aspect of the structural Engineering at the academic level and from this scale of projects, they have to practice the practical application of those. This will tend to deliver some failures as the Engineers lack of experience in practicality. Implementation of the proposed application by engineers is often very difficult in the real world. This is mainly due to the lack of practical sense in the constructions.

Therefore, as Professional Engineers, they should be very careful when they are involving in particular projects, where people trust their professionality and seeking proper solutions. The deliverables should be matching the common standards in the field for structural engineer in practice.

5.1.4. Engineers lack confidence and communication skills

Priority responses in figure 9 and table 8 show that there has been a communication gap between professional engineers and the laymen in the house constructions. Even though the validation will give the opposite of that. It will imply that there can be communication gap as

well as confident level problems of engineers who are practicing in the house constructions but the relationship with structural failure for that was not significant.

This will conclude that even though the Engineers have less confident about the project that they have undertaken, the probability of success is not affected. It was not guaranteed that this study generates a holistic picture of the real scenario. But as per the sample and data analysis, we can conclude the above statement.

Initially, there were some language barrier and misunderstanding of technical wordings between Engineers and laymen. But with the experienced engineers will tend to develop their ability to mitigate those misunderstanding in no time.

Engineers should improve their confidence and communication skills in order to deliver technical inputs to the desired stakeholders. Confidence and communication skills generally improves with the experience. However, need much more focus and efforts to improve these skills using modern techniques such as accessing Toastmaster clubs, NLP, meditation, visualization, affirmation, etc.

5.2. Summary of the conclusion

The structural failure of house construction may be occurred mainly due to the Labors lack of knowledge and manipulations seeking advantages. The relationship between the two factors was very strong in this case. Then there are other two factors which will affect the structural failures of house construction on a lesser scale than the above, which are Clients lack of knowledge and misunderstandings and Engineers lack knowledge and experience. Also Engineers lack of confidence and communication skills play vital role in contemporary Sri Lanka that has to be developed by each and every Engineers using modern techniques.

5.3. Recommendations

The objective of this research is to find out the optimizing process and solution to avoid or minimize structural failures by the intervention of the incompetent people to structural designs of houses. Therefore, from the previous chapter that we have concluded that Structural failures in house constructions are mainly caused due to the involvement of the

incompetent people during the constructions. Therefore, we can draw the following recommendation to mitigate the structural failures in the house construction projects by considering all the factors in the literature review, data analysis using data from the survey.

5.3.1. Recommendations to mitigate the factors affecting structural failures in house constructions

- **Clients lack of knowledge and misunderstandings**

  It can be recommended that from the client viewpoint, they should be very careful with the structural concerns for their house construction even though it may involve an additional cost. Initially, it can be an additional cost but it could be more additional cost in the future due to the failure and rectifications. In the present context, more clients have tended to consult a professional engineer prior to the construction of the house. But yet there is a majority who do not practice that. This research recommends that all clients should consider the structural concerns for the building carefully as similar as they have a concern about the finishes and decorations to prevent any structural failures in the future. Awareness campaigns among community bases could be a better solution in these perspectives.

- **Labors lack of knowledge and manipulations seeking advantages and Engineers lack knowledge and experience**

  Labors and the Engineers should work in hand to hand to minimize these factors affecting structural failures. Engineers should build a strong relationship with the labors as well as vice versa. Then they will tend to depend on each other for any decision making. This will create a cohesiveness among the two parties to work together to achieve a synergy effect. Experience of the labors and the Expertise of the Engineers can be combined together to deliver a perfect product for the client which will be more cost-effective, more sustainable and more structurally stable.

5.4. Future Research

This research has been focused only on the major factors affecting structural failures of the house constructions that have been identified via experts' opinions and the survey. Further development of these factors and any other relevant factors which this researcher has not been considered can be tested for validation. Sample collection also has been limited to the western province of Sri Lanka by the researcher for the purpose of convenience in collecting data as per the snowball data collection technique.

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7. ANNEXURE

7.1. ANNEX 01 – Client Base

Basic Information

- Job Title:
- Exposure to construction (high/medium/low)
- Number of Projects involved (Number):

Possibility of structural failure

1 Possibility of structural failure of a house due to the poor construction
2 Possibility of structural failure of a house due to not following professional design
3 Experience of structural failure due to unidentified circumstances

Client's lack of knowledge and misunderstandings

1. Possibility of getting detail design from the structural Engineer for the housing project
2. Possibility of Structural failure in house construction due to the amendment made to original scope without considering structural concerns
3. Awareness of the structural concerns for the house in general

Labor's lack of knowledge and manipulations seeking advantages

1. The likeness of amending the structural details by the labors at the site for their practical convenience
2. Possibility of structural failure in house construction due to alterations proposed by the labors to the initial design
3. The likeness of getting the project done by the labors rather than involving professionals

Engineers lack knowledge and experience

1. Possibility of having professional qualified Engineer full time at the construction site
2. Possibility of practicing given details in structural design at the site

Engineers lack confidence and communication

1. Possibility of assigning a Structural Engineer in the practical application of the structural design in the house construction
2. Possibility of the Communication Gap between Professionals and Laymen's (Client, Labor)

7.2. ANNEX 02 - Skilled or Unskilled Labors

Basic Information

1. Living Area:
2. Working Area:
3. Skilled Level (USL/SL):
4. Experience in the field (Years):
5. The number of projects involved:

Possibility of structural failure

1 Possibility of structural failure of a house due to the poor construction
2 Possibility of structural failure of a house due to not following professional design
3 Experience of structural failure due to unidentified circumstances

Client's lack of knowledge and misunderstandings

1. What is the likeness to get all detail clarification about the project from a professional Engineer full-time basis?
2. Possibility of occurring structural failures due to absent of the Engineers supervision?
3. Possibility of occurring structural failures due to client's additional changes to the original design?

Labor's lack of knowledge and manipulations seeking advantages

1. Possibility of using any alternative method other than the Engineers proposal for the construction process?
2. Possibility to undertake housing project without any Professional Engineer's involvement?
3. Expert knowledge of labors about the structural requirement for House Construction project in general?

Engineers lack knowledge and experience

1. Possibility of executing the details suggested by the Professional Engineer in the practical situations
2. Possibility of occurring additional time and cost due to the proposed designs of structural Engineer

Engineers lack confidence and communication skills

1. Possibility of occurring structural failure due to practicing Structural Engineer's proposed details
2. Possibility of the Communication Gap between Professionals and Laymen's (Client, Labor)

7.3. ANNEX 03 - Professional Engineer

Basic Information

1. Working Area:
2. Experience in the field (Years):
3. Highest Qualification:
4. Number of Projects involved (Number):

Possibility of structural failure

1 Possibility of structural failure of a house due to the poor construction

2 Possibility of structural failure of a house due to not following professional design

3 Experience of structural failure due to unidentified circumstances

Client's lack of knowledge and misunderstandings

1. Possibility of getting done detail design by the client for housing projects
2. Possibility of having professional qualified Engineer full time at the construction site
3. Possibility of Structural failure in house construction due to client's amendment to original scope without considering structural concerns

Labor's lack of knowledge and manipulations seeking advantages

1. The likeness of amending the structural details by the labors at the site for their practical convenience
2. Possibility of structural failure in house construction due to alterations proposed by the labors to the initial design

Engineers lack knowledge and experience

1. The likeness of the Structural Engineer's involvement in the practical application of the structural design in the house construction due to the scale of the project
2. Possibility of structural failure due to design failure in house constructions
3. Possibility of practicing given details in structural design at the site

Engineers lack confidence and communication

1. Possibility of structural failure in house construction due to lack of supervision of qualified professional Engineer
2. Possibility of the Communication Gap between Professionals and Laymen's (Client, Labor)