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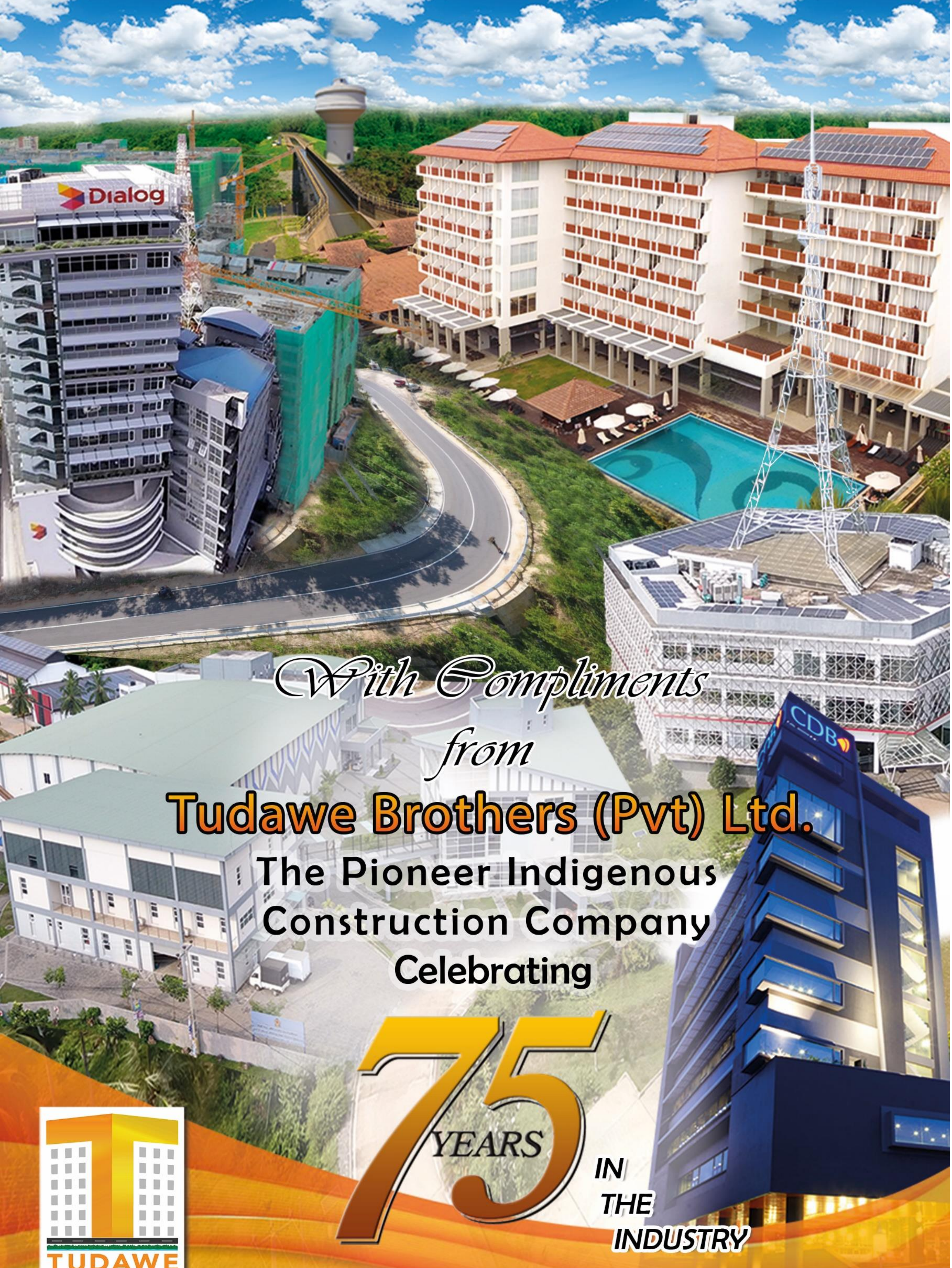
வாருங்கள் நாங்கள் ஒரு நெட்வொர்க் வே
TOWARDS A GREENLY CONNECTED SOCIETY”

Ministry of Housing & Construction

Construction Industry Development Authority

“Savsiripaya” No.123, Wijerama Mawatha, Colombo 07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CONTENTS

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MESSAGE FROM THE DIRECTOR GENERAL...

Construction Industry Development Authority which is the apex body in Construction Industry is mandated to regulate, register, formalize and standardize the activities of the Construction Industry.

The Construction Industry is growing at a very rapid pace witnessing a growth rate of 9.3% at the end of 2nd quarter of the year 2017.

The Construction Industry plays a major role in national economy development contributing more that 8% to the Gross Domestic Product (GDP).

In order to sustain this massive immerging growth of the Construction Industry it is to be ensured that resource requirement of the Construction Industry are adequately met.
The meeting of the increased requirement of the industry in a sustainable manner creating minimum impact on environment is becoming increasingly difficult due to the ever increasing demand and resource requirement of the industry must be made available.

The excessive use of natural resources more than the rate of the regeneration may cause additional stresses on the ecological systems leading to threatening of their existence. This situation urges that innovative approaches are urgently required to meet these emerging demands in the Construction Industry in a sustainable manner.

The Construction Industry Development Authority conducts National Construction Excellence Awards Ceremony to identify and reward construction companies who have achieved excellence in their respective fields setting bench marks.

In parallel to this national ceremony Construction Industry Development Authority publishes this refereed journal in order to disseminate the knowledge on new trends and innovations immerging in the Construction Industry providing sustainable solutions to the issues mentioned above creating scientific dialogue leading to more research and development to take the industry forward.

I take this opportunity to thank all the Authors for submitting their professional and visionary articles to be published in this valuable journal for the benefit of construction community.

I must appreciate the valuable guidance and advice provided by the Hon. Minister for compiling this scientific journal. I also highly value the directions given by the Secretary and Ministry officials facilitating the completion of this Journal.

I also thank the editorial board for their commitment, dedication and professional contributions to make this journal a success.

My appreciation also goes to Director (Development) and staff of the Development Division publishing this journal on this important day of celebrating the achievements of the stakeholders of the Construction Industry.

Archt. H. K. Balachandra, BSc. (BE), MSc. (Arch.), AIA (SL), RIBA, Chartered Architect.
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CHALLENGES IN HIGHWAY CONSTRUCTION PROJECTS IN SRI LANKA

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ABSTRACT

Highway construction projects have created a strong aspiration to social and economic growth in the recent past in Sri Lanka. With the rapid increase of highway constructions along with visible challenges, it has become necessary to introduce sustainable practices to highway construction projects to have a rewarding outcome at the end. Therefore, the aim of this paper is to identify the prevailing challenges and introduce sustainable solutions and thereby improve the quality of upcoming highway construction projects in Sri Lanka.

A comprehensive literature review followed by 48 questionnaires was used to gather data and was analysed with factor analysis method using SPSS. Twelve key challenges which include financial, political, social, resource related, safety related, research and development related, skill related, technical and technological, administration coordination, training development related, operational, third party challenges were identified. Financial and political challengers were recognized as the most significant. Use of economically viable, environmental and social friendly designs, local materials and local financial resources, application of the value engineering, implementing construction safety practices, introducing new construction quality standards were several probable solutions to reduce the complexity of the highway construction projects in Sri Lanka and increase the benefits. Further, the practicability and transparency of the probable solutions were considered when drawing the sustainable solutions.

Keywords: *Highway construction projects, sustainable solutions, challenges, causes*

1. INTRODUCTION

Different modes of transportation systems have origin as a solution to the boost of traffic volumes around the metropolitan areas [1]. Highway construction has become one mode of transportation and solution to high traffic flows. Highway construction projects facilitate numerous inducements to the development of country through straightforward transportation [20]. The growth of the highway construction industry is grounded on regime choices, rules and events which have an understandable connection among appropriate administration performs and methods [6].

Sri Lanka is a developing country and the highway construction industry launches a large share of economy by accommodating several highways and expressways such as Katunayaka highway, Outer Circular Highway (OCH), Southern highway [22]. Consequently, Highway projects in Sri Lanka confront daunting challenges as it in the inaugural stage [22]. This could include financial, environment, political, social challengers and economic challengers [1]. A wide area of social, economic and environment should consider while dealing with decisive challenges in highway construction projects [21]. Therefore, focusing on sustainable solutions is apposite for this purpose.

In Sri Lankan context, lack of sustainable solution for challenges in highway projects limits the successful completion of projects within projected cost and period [10]. Therefore, study focuses to identify the sustainable solutions for vital challengers which hinder the development of highway construction. Scope of the paper covers the comprehensive literature review, research methodology, research findings, and conclusions respectively.

2. LITERATURE REVIEW

A strong alliance of several facets such as economic, financial and environmental, facilitate for a successful highway construction project [4]. Furthermore, novel road development projects demand new sustainable initiatives without conciliation traditional road construction practices [18]. Consequently, as major construction project throughout the country, it permissible a greening built environment and to be more sustainable [23]. However, critical evaluation of vital challengers which affect the adaptation of sustainability in highway construction projects is required before focusing on the sustainability initiatives [26]. Furthermore, main key challengers find through previous researches are common to the countries under the "developing" status, impact and severity subject to change with the country [7].

2.1 Challenges Faced By Highway Construction Industry

Challenges faced by highway construction projects are categorized among different fields according to the causes and its impact [8]. Mainly, it occurs due to the external influencing factors around the construction project such as environment facts, social facts and economical facts [12]. However, literature review highlights twelve core challengers as financial challenges, political challenges, social challenges, resource related challenges, safety related challenges, research and development related challenges, environmental challenges, technical and technological challenges, administration and coordination challenges, training and development related challenges, operational challenges, and third party challenges.

2.1.1 Financial challenges

It is apparent that numbers of financial challenges are around the expected amount and the actual consumption during the construction project [12]. According to Harvey [12], financial challenges identified as variation in taxation, loans, inflation and variations in the design and level of its spending. Moreover, Hassanein and Khalifa [13] mentioned causes for the financial challenges as poor management of cash flows, high inflation proportion, slight profit boundaries, insufficient support from banking segment, high interest amount for finances and quick change in nationwide budget. As a result, it impact on project cash flow, profitability and numerous financial dealings, and increase the risk of extinction of the project in the short run [28].

2.1.2 Political challenges

Lobina [19] revealed that political challengers approaching across highway construction industry due to political instability and unpredictability. Further, Hassanein & Khalifa [13] emphasised numerous causes for the political challenges such as political unpredictability, restrictions of introducing new materials and equipment, level of government support in highway construction, bribe, dishonesty and favouritisms, changes in laws and government policies on taxes.

2.1.3 Social challenges

Social challenges refer to the challenges which occur due to the disagreement of the public and other private organizations in the process of highway construction [17]. Further, Laube, & Giesen [17] stated that land acquisition as a crucial challenge faced by highway construction project. The causes for the social challenges are high level of environment influence, inadequate facilities for labour, cumulative urbanization, inadequate flexibility of effort force, and disagreements of public with the highway construction [11]. According to Aibinu & Jagboro [3] insurance challenges also categorized under social challenges.

2.1.4 Resource related challenges

It is apparent that shortage of resources to execute the construction is a resource related challenge [26]. Furthermore, Author highlighted inappropriate administration standards of contracting, absence of high technical manufacture equipment, high competition and partnering, inadequate addition on design and built processes, problems by rented equipment, high labour turnover and multi layered sub-contracting system as causes behind these challengers.

2.1.5 Safety related challenges

Lack of safety precautions is the prominent challenge goes under safety related challengers [9]. Kumaraswamy [16] research study identified six important causes for the safety related challenges such as indeterminate requirement of construction safety, inadequate safety precautions, improper applications of safety instructions, and inadequate capitals allocation for safety precautions, inadequate knowledge on safety precautions and lesser employment of safety officer.

2.1.6 Training and development related challenges

For any construction industry training and development is very significant since it inject new technical and technological skills [14]. Training and development related challenges come across when implementing new training programs to the employees and process of increasing labour performances [14]. Ahsan and Gunawan [2] emphasised several types of trainings engaged with the highway construction projects as technical training, skill training, safety training, managerial training and professional training. Perera and Imriyas [25] identified four vital causes for training and development related challenges which are insufficient carrier development programme, inadequate support from institutional, active government presently and distribution of capitals for employee trainings classifying schemes are inadequate.

2.1.7 Environmental challenges

There are several aspect should be considered prior to initiate the highway construction and several measures should be taken concerning the weather predictions [24]. Unexpected weather changes, tsunami attack, floods, heavy rain and heavy wind form environmental challenges [5]. Influence from the environmental authorities highly affect the highway construction projects since it affect to the biodiversity of the region [24].

2.1.8 Technical and technological challenges

In developing countries lack of technical and technological knowledge amongst the people is a massive challenge in any construction projects, it’s more crucial in highway construction since there are cost and time overruns [13]. Kumaraswamy [16] specifies the vital causes for technical and technological challenges such as less of technology transmission, lesser usage of IT in highway construction, inappropriate assortment of suitable technology, insufficient technological information and low level of different technological expansion.

2.1.9 Administration and coordination challenges

The key and foremost task of administration is to manage stakeholders by managerial operations and implementing coordination between all parties [15]. poor documentation procedure, undefined job scope, poor cost planning, poor communication, lack of development monitoring, disorganization in decision creation, low level of organizational elasticity, widespread period slippage in contracts commenced and lack of coordination between client and contractor are the causes behind these challengers [12].

2.1.10 Operational challenges

Mainly, operational challenges occur while undertaking the maintenance of the highway. Lobina [19] noted that high operational cost for highways, operational dangers, and highway traffic management difficulties during maintenance, lack of facilities for maintenance as main causes for operational challenges.

2.1.11 Third party challenges

Lobina [19] emphasised that highway construction industry confront many challenges from ghastly behaviour of workers and civil public. Furthermore, author mentioned causes such as theft, theft in electricity supply, theft in water supply and theft in telecommunication lines. Moreover, telecommunication lines, electricity supply and water supply have been indirectly changeable and disturb the whole cost factor of the highway construction projects [27].

2.2 Sustainable solutions to overcome challengers in Highway construction projects

The selection of number of solutions depends on number of factors and criteria of the challenge. In terms of sustainability it should address the economic, social and environment aspects [26]. Integration and collaboration between economic, social and environment facts augment the successful adaptation of sustainable practices in highway road development. However Marin [20] stated that practicability and transparency are essential in providing sustainable strategies for any projects. Therefore, number of prior indicators and settings should follow based on the severity of the challenge.

Li and Wang [18] stated that substitution of the traditional process with alternative environmental, social and economical straightforward methods as one way of providing sustainability in highway road construction projects. Furthermore, Gordon [9] emphasized that administration control by better society focus system is vital for the sustainability phenomena. Renewable electricity hub, CO2 reduction strategies, regional electricity balance are one way of maintain environmental friendly surroundings in highway construction projects [1]. Use of environmental friendly designs, local materials and local financial resources are solutions to balance the three pillars of sustainability [9].

Having considered the above review, this research study intends to investigate practical solutions for the challengers in highway construction projects in terms of economic, environment and social phenomena for effective and efficient functioning of project.

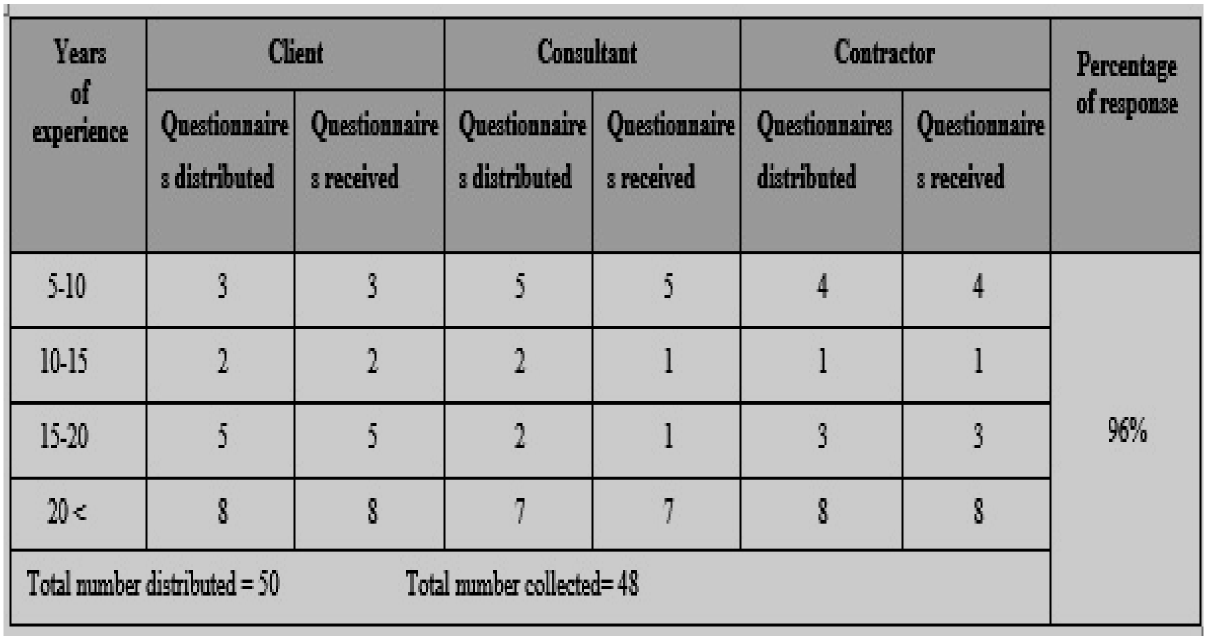
3. RESEARCH METHODOLOGY

The research initiated with a literature synthesis to locate the common challenges in highway construction industry in Sri Lanka. The survey approach was adopted as the best suitable method for the research among Quantity Surveying professionals working in Sri Lankan highway construction firms to ascertain their experience regarding challenges in highway construction projects. Questionnaire survey method used as the data collection technique in this research. Questionnaires were distributed among 50 Quantity Surveying professionals; out of the 50 questionnaires 48 questionnaires were collected. T-test, factor analysis and RII method were used as the data analysis techniques by using Statistical Package for Social Science" (SPSS) software to analyse the challengers with causes and rank them according to the significance. Finally, Nine (09) experts in highway construction projects were interviewed to gather sustainable solutions to the respective challenges.

4. DATA ANALYSIS

As mentioned in the previous section 48 Quantity Surveyors responded to the questionnaire. Table 1 represents the combination of the respondents under different categories.

Table 1: Survey Response Rate



Years of experience	Client		Consultant		Contractor		Percentage of response
	Questionnaires distributed	Questionnaires received	Questionnaires distributed	Questionnaires received	Questionnaires distributed	Questionnaires received	
5-10	3	3	5	5	4	4	96%
10-15	2	2	2	1	1	1	
15-20	5	5	2	1	3	3	
20 <	8	8	7	7	8	8	
Total number distributed = 50			Total number collected= 48				

According to Table 1 out of the 48 respondents 12 were having an experience of 5-10 years. The major percentage of nearly 50% (23 out of the 48 respondents) respondents have an experience above 20 years which enabled the researcher to gather reliable data.

4.1 Challenges in highway construction projects

Based on the results of the questionnaires, 12 significant challenges were identified. As the first step of the analysis, major challenges were arranged in the priority order using the relative important index (RII). Second step of the analysis was giving weights for each challenge; Challenge with the highest weight was considered as the most important challenge and less important challenges obtained a lower weight. Significant challenges for the all parties (client, consultant and contractor) were identified as shown in Table 2 in priority order.

Table 2: Rank of Challenges in Priority Order

Challenges	**RII**	**Rank**
Financial challenges	0.0833	1
Political challenges	0.1718	2
Social challenges	0.3993	3
Resource related challenges	0.4166	4
Safety related challenges	0.4739	5
Research and development related challenges	0.4913	6
Skill related challenges	0.5798	7
Technical and technological challenges	0.5920	8
Administration and coordination challenges	0.7100	9
Training and development related challenges	0.7378	10
Operational challenges	0.8541	11
Third party challenges	0.9340	12

According to Table 2 it is clearly evident that the financial challenges are the most important challenges with the lowest RII 0.0833 and highest weightage 12. In the ranking order political challenges ranked second with a RII 0.1718 and weightage 11. Social challenges were ranked third with a RII 0.3993 and weightage 10. When considering the challenges faced by all three parties (client, consultant and contractor) these three were ranked at the top in the ranking scale with lowest RII and highest weightage. Training and development related challenges (RII 0.7378), operational challenges (RII 0.8541) and third party challenges (RII 0.9340) were ranked lower which indicated that they have a less significance compared to the other challenges.

4.2 Causes for challenges in highway construction projects

Next step of the research process was identifying the causes for the challenges indicated in the above section. Accordingly the causes for the above 12 challenges were recognized through the questionnaire survey. Financial challenges were recognized as the prime challenge faced by the three sectors, therefore the causes for financial challenges were identified first.

4.2.1 Analysing the causes for challenges

Rotated component matrix method is used to identify the factor loadings for each variable which will determine significant factors [27]. In order to identify the most significant causes of financial challenges factor analysis method and rotated component matrix method were used. From literature review 6 causes were identified under the financial challenges, out of the 6 causes 3 most significant causes were filtered by t-test and factor analysis method. Tables 3, 4 and 5 represent the method of factor analysis by using SPSS software.

Out of the 6 major causes mentioned in Table 3, slight profit boundaries can be rejected since significant value of that cause is 0.569. Confidence interval considered in this research is 95% and consequently if the significant value of the cause over 0.05 it should be rejected. Out of the remaining 5 causes, high interest amount for finances is ranked at the top with the highest t-value and RII. Subsequently high inflation proportion and quick change in nationwide budget were ranked at 2nd and 3rd places.

Table 3: t-value and RII for Financial Challenges

No	**Causes for the financial challenges**	**t-value**	**RII**
A2	High interest amount for finances	15.725	17.553
A6	High inflation proportion	12.956	17.250
A4	Quick change in nationwide budget	5.189	15.250
A1	Poor management of cash flows	5.511	14.583
A3	Insufficient support from banking segment	4.064	14.595
A5	Slight profit boundaries	0.573	

Pool factor analysis method can be used to determine the key factors from a pool of data [27]. In order to choose the most important cause from this pool factor analysis method was used. Table 4 represents the way of factor analysis.

Table 4: Total Variance for Financial Challenges

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	%of Variance	Cumulative %	Total	%of Variance	Cumulative %
1	2.452	49.045	49.045	1.789	35.786	35.786
2	1.114	22.280	71.325	1.417	28.350	64.135
3	.728	14.562	85.887	1.088	21.752	85.887
4	.470	9.406	95.293			
5	.235	4.707	100.000			

Initial eigenvalues and rotation sums of squared loadings were calculated for the factor analysis process.

Table 5: Rotated Component Matrix for Financial Challenges

	Component		
	1	**2**	**3**

-Poor management of cash flow	0.098	0.946	-0.053
-High interest rate for finances	0.884	0.149	-0.079
-Insufficient support from banking segment	0.548	0.680	0.100
-Quick change in nationwide budget	0.831	0.195	0.334
-High inflation proportion	0.088	-0.018	0.978

According to the Tables 4 and 5, the 5 causes were mainly divided into three components using rotated component matrix and total variance by using SPSS software. In each component the cause which took the highest value is the significant cause according to the statistics. High interest rate for finances has indicated the highest value of 0.884 in component 1. Consequently poor management of cash flow has indicated the highest value (0.946) in component 2 and high inflation proportion has indicated the highest value (0.978) in component 3. Accordingly the three major causes for financial challenges are,

- High interest amount for finances
- High inflation proportion
- Quick change in nationwide budget

Similar calculations were made for all the issues identified above and two/three major causes were identified for each of the challenges.

Table 6: Causes for the Identified Challenges

Challenges	Causes
1. Financial challenges	-High interest rate for finances -Poor management of cash flow
2. Political challenges	-Restrictions of introducing new materials and equipment -Government bureaucracy in highway industrial practice -Political unpredictability
3. Social challenges	-Inadequate fitness on construction locations -Inadequate facilities providing at site for labour -High level of environment influence
4. Resource related challenges	-Absence of high technical manufacture equipment -Problems by rented equipment -High competition and partnering
5. Safety related challenges	-Inadequate capitals allocation for safety precautions -Lesser employment of safety officer -Indeterminate requirement of construction safety
6. Research and development related challenges	-Limited distribution of assets for research -Unenthusiastic in using advanced materials
7. Skill related challenges	-Shortage of skills obtainability in construction -Low level of skill growth programme -Shortage of specialists
8. Technical and technological challenges	-Low level of different technological expansion -Lesser usage of IT in highway construction -Inappropriate assortment of suitable technology

9. Administration coordination challenges	-Poor communication -Widespread period slippage in contracts commenced -Poor cost planning
10. Training development related challenges	-Insufficient carrier development programme -Inadequate distribution of capitals for employee trainings
11. Operational challenges	-Operational hazards -Traffic management difficulties during maintenance -High operational cost for highways
12. Third party challenges	-Employee theft -Theft in electricity supply

Table 6 indicates the causes identified for the challenges in highway construction in prioritized order.

4.3 Sustainable Solutions for the Challenges in Highway Construction

In order to achieve the objective of this research the next focus was on identifying sustainable solutions for the identified challenges. Accordingly 09 experts in highway construction industry were interviewed.

According to the respondents, the number of factors that can be controlled by the contractor (or the builder) is limited. Respondents have indicated the following as some of the key areas that can be controlled by the contractor during the highway construction projects.

- Materials used during the mining, processing and construction of the highway
- Factors related to design which controls the types and quantities of the materials, energy use in the future and resource usage in the future etc.
- Factors such as bio diversity loss, future noise and social impacts
- Transient construction impacts ex: dust, on site energy use, noise, occupational health and safety etc.
- Life time issues such as upgrading and changing, longevity and potential for material recovery at the end of the life.

However in order to maintain sustainability in highway construction projects it is essential to make sure that each and every loophole is covered. Accordingly respondents have made some suggestions for the sustainable construction of the highways which will also resolve many of the issues identified above.

4.3.1 Materials used during construction

As indicated above, materials used during the mining, processing and construction of the highway has a significant impact on several aspects. Majority of the respondents (7 out of 9) confirmed that it directly impacts to all the challenges except the political challenges. Therefore providing solutions for this issue was considered as a major step towards sustainability of highway construction.

One solution suggested by 5 of the respondents was using pre cast concrete for the construction process. Respondents indicated that a major cost reduction and a significant reduction of environmental impacts can be achieved by this solution.

Similarly respondents indicated several solutions such as use of new machines with advanced technology which also provides solutions for the transient construction impacts, use of LED lighting which also has a positive impact to the life time issues of the construction project, recycling of materials etc.

4.3.2 Design Factors

Respondents considered this as the second most significant factor that will enhance the sustainability of highway construction. According to the respondents most of the designs used in Sri Lankan highway projects are not up to date. Therefore one of the main suggestions of the respondents was to adopt latest, advanced designs for the highway construction projects. According to the respondents it will be an ideal solution for many issues related to environment, social and financial aspects in the long run.

Apart from that respondents have indicated that many of the developed countries have adopted sustainable designs for highway construction projects which are applicable to the Sri Lankan context as well. These designs however have cost implications which reduce the adoptability to the Sri Lankan context.

4.3.3 Transient construction impacts

According to the respondents transient construction impacts are the least considered effects of highway construction. Many of the contractors have given less consideration to these impacts due to the elimination of many of these impacts after the close of the project. However these impacts reoccur in the next construction project again.

Therefore the respondents suggested to solve these issues by implicating regulations related to these elements. Even though there are current regulations in operation, due to the loopholes in the system many contractors escape. Suggestion of the respondents is to adopt international regulations and initiate a strict monitoring process throughout the construction process.

4.3.4 Environmental and social impacts

Environmental and social impacts are the largely visible challenges of highway construction projects. Many of the government and non-government organisations have addressed these issues. However the respondents indicated that many of these issues went unnoticed due to political and other influences and no proper solutions were provided for these issues.

Accordingly the respondents suggested to adopt strict environmental regulations. Apart from that 3 respondents suggested to establish environmental policies. Furthermore respondents recommended periodical environmental impact surveys to be conducted during the highway construction process.

Social challenges are another key set of challenges that have a significant impact to the highway construction projects. According to the respondents these challenges are extremely difficult to overcome because the challenges differ from one area to another. Therefore the respondents suggested to establish a separate division in the contracting organisation to manage the social issues arising during the highway construction process.

5. CONCLUSIONS

It is evident through the research findings that even though the Sri Lankan highway construction industry is relatively new has to face several challenges. These challenges have a significant impact towards the construction process as well as the final outcome. According to the research findings which were based on 48 questionnaire responses, financial challenges were recognized as the most significant set of challenges. Subsequently political challenges and social challenges were ranked at second and third places.

T-test analysis was used to identify the causes for the above challenges. Based on the t-test and factor analysis several causes were identified. Among the identified twelve causes Financial Challenges recorded the lowest RII value of 0.0833 which indicated that Financial Challenges are the most significant challenges in highway construction in Sri Lanka. Based on the rotated component matrix analysis of causes for financial challenges high interest amount for finances 0.884 in component 1, high inflation proportion 0.946 in component 2 and quick change in nationwide budget 0.334 in component 3 were recognized as the three major causes. Similarly key causes for all the identified challenges were prioritized.

As the next step of the research 9 experts in the highway construction industry were interviewed to find sustainable solutions for the challenges in highway construction projects. Accordingly solutions were discussed under five main topics. According to the respondents these solutions are tough to implement. Therefore it is necessary to identify the key barriers and enablers to implement these solutions.

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APPLICABILITY OF PANELIZED WALL SYSTEMS FOR BUILDING PROJECTS IN SRI LANKA

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ABSTRACT

A majority of wall construction in Sri Lanka uses bricks and blocks, and the usage of the traditional on-site wall construction methods have raised some serious issues, particularly with respect to quality and time. In recent past, Modern Methods of Constructions (MMC) are suggested to deal more efficiently with construction to avoid issues inherent with traditional construction methods. Panelized wall *construction is one such method, belonging to the broad category of off-site MMC. It is the process where wall panels are manufactured under the factory conditions according to the requirements and transported to the site for assembling into a structure. However, the panelized system is still not popular among the industry stakeholders, and thus, the present paper aims to determine the applicability of panelized wall systems for building projects in Sri Lanka.*

This study indicates the opinions of different construction professionals, representing project managers, engineers, architects, and quantity surveyors, regarding the applicability of panelized wall systems. This research was performed through a structured questionnaire survey, which revealed that majority of construction professionals in the industry are aware of panelized wall construction. Reduced construction time and increased quality were identified as significant advantages of the panelized wall method compared to traditional wall construction methods, while lack of awareness, skilled labour shortage, client resistance, and lack of guidance, were recognized as key disadvantages to the establishment of panelized wall construction.

The results further revealed that precast concrete panel is the highest applicable panelized wall system for external and internal walls of industrial buildings, whereas structural insulated panel is the most appropriate panelized wall system for commercial buildings. The study also found that precast concrete panels and structural insulated panels have characteristics of high strength, durability, less wastage, and less maintenance. Construction professionals further believed that precast concrete panels and structural insulated panels receive a higher demand compared to other panelized wall systems.

Key words: *Modern Methods of Construction, Off-site, Panelized Wall Construction, Panelized Wall Systems, Building Projects, Sri Lanka*

1.0 INTRODUCTION

One of the most common methods of wall construction is the use of bricks and blocks; this is known as the traditional method of construction and also referred to as on-site construction (Sigurdardottir, 2012).Although a majority of houses are still built traditionally (Taylor, 2015), the usage of traditional on-site wall construction methods have raised some serious issues, especially in the areas of quality, time, and cost (Sarden & Engstrom, 2006). Moreover, the authors mentioned that the progress of conventional on-site construction methods is constrained by the availability of trades, coordination of the delivery of products, services to the building site, and weather-related delays. These problems continued throughout the past few years and influenced the efficiency of building construction industry.

Modern Methods of Constructions (MMC) are suggested to deal more efficiently with uncertainties inherent in traditional construction regarding time, defects, and safety (Sarden & Engstrom, 2006) and these modern methods of construction are not novel in developed countries in Europe and the USA (Kyjakova, Mandicak & Mesaros, 2014).

Kyjakova et al. (2014) also stated that MMC could be identified as an innovation in construction. The methods introduced into UK house building differ significantly from so-called conventional construction methods such as Brick and Block (Cartwright, Novakovic & Ross, 2006). Literature bears evidence of three main types of off-site MMC, which can be named as volumetric construction, panelized construction, and the hybrid construction (National Audit Office, 2005). Among them, panelized construction system is factory-produced flat panel units, transported to the site and assembled into a three-dimensional structure or fit within an existing structure (Cartwright,Novakovic & Ross,2006). As depicted in literature, panelized systems can be used for walls, floors, and roof panels, to create the complete structural shell. These systems include Structurally Insulated Panels, Semi-Structurally Insulated Panels (Structural Insulation & Frame), Multi-layered Engineered Timber (Solid), and Precast Concrete Panels (Engstrom & Sarden, 2010).

While panelized wall construction is a widespread off-site building technology, it has only been used in a limited manner, and its real benefits are mostly untapped (NAHB Research Center, 2003). The usage and awareness of the panelized construction systems are still not wide spread nor significantly mentioned anywhere in building construction sector in Sri Lanka, despite its various benefits over conventional methods. Therefore, this research expects to determine the applicability of panelized wall systems for building projects in Sri Lanka.

2.0 LITERATURE REVIEW

2.1 Modern Method of Construction (MMC)

Modern Method of Construction (MMC) is a generic term used to describe several construction methods that differ from traditional methods of construction applied in the industry (Kempton, 2009). It has several meanings such as off-site construction, factory-built, and prefabrication (Ross, Cartwright & Novakovic, 2006). The study of Mesaros, Mandicak, and Kyjakova (2014) stated MMC as a common term for off-site methods of construction and on-site methods of construction.

Off-site MMC is prefabrication elements or parts of structures constructed in a factory and transported and assembled on-site. On-site MMCs are building blocks and parts of structures built directly on-site. Chen (2010) argues that MMC in the construction industry enhance productivity and improve the quality. Its main benefits are, shortened construction time, lowered overall construction cost, and higher quality. Enhancement of durability, better architectural appearance, enhancing occupational health and safety, material conservation, less construction site waste, less environmental emissions, and reduction of energy and water consumption are highlighted as other key benefits of MMC. Nadim and Goulding (2003) claimed that off-site construction (OSC) is a sub-category, which falls under the broader purview of MMC. Moreover, the author emphasized that all off-site can fall under the MMCs, but all MMCs are not off-site. Ross, Cartwright, and Novakovic (2006) described the MMC types used in the industry and listed them as Volumetric construction, Panelized construction, Hybrid construction, Sub-assemblies and components, and Site based systems (on-site). A brief definition of each type is given below:

Volumetric construction: Ross, Cartwright, and Novakovic (2006) define volumetric construction as three-dimensional units produced in a factory and fully fitted-out before being transported to the site and stacked onto prepared foundations to form the dwellings. Volumetric construction is also referred to as modular construction.

Panelized construction: Flat panel units are built in a factory and transported to site to assemble into a three-dimensional structure or to fit within an existing structure. These systems include wall, floor, and roof panels, to create the complete structural shell. Panelized construction is also known as 'non-volumetric pre-assembly', where the elements are supplied in a 2D flat panel format (Goodier & Gibb, 2007; Mapston & Westbrook, 2010).

Hybrid construction: This method consists of volumetric units integrated with panelized systems which combine both panelized and volumetric approaches. Hybrid construction is also referred to as semi volumetric construction. Highly serviced areas such as kitchens or bathrooms can be constructed as volumetric units, while rest of the dwelling is built with panels (Ross, Cartwright & Novakovic, 2006).

Sub-assemblies and components: This category covers factory built sub-assemblies or components in an otherwise traditionally-built structural form; typically, schemes incorporating the use of floor or roof cassettes, precast concrete foundation assemblies, preformed service installations, and cladding systems.

Site-based systems: These are the innovative methods of construction used on-site where conventional components are used in an innovative way (Ross, Cartwright & Novakovic, 2006). A variety of systems are available such as,

- Tunnel form *in situ* concrete
- Insulating formwork
- Air Crete

MMC has played a key role in the construction industry during the past few decades and is significantly becoming a major alternative method and a strategic direction compared to traditional *insitu* method.

2.2 Panelized Construction Systems

As discussed in Section 2.1, MMC can be divided into off-site MMC and on-site MMC. Panelized construction is one of the off-site construction techniques (prefabrication methods), which belongs to the off-site MMC. As mentioned earlier, panelized construction is also known as non-volumetric construction where 2D flat panel units do not enclose usable space (Build Off site, 2006; Mapston & Westbrook, 2010). Auger (2015) describes the panelized construction as 'the process of constructing a modular wall, roof, and floor sections, in an environmentally-controlled manufacturing facility and delivering them to the construction site for installation. Flat panel units of walls, floor, and roof, are manufactured under factory conditions and delivered to site to assemble into a three-dimensional structure or to fix within an existing structure (NAHB, 2004; Steinhardt, Manley & Miller, 2013).

As depicted in literature, the construction industry uses several types of panelized wall systems. Ross, Cartwright, and Novakovic (2006) have grouped panelized wall systems into five categoriesas; i) Precast concrete panels, ii) Composite panels, iii) Structural insulated panels(SIP), iv) Infill panels, and v) Curtain walling. Moreover, Westbrook and Mapston (2010) mention about another two-panel construction systems; Timber frame panels and Light weight steel frame panels. These Panelized systems can either be open, which are typically delivered to the site purely as a structural element, or closed, which usually include additional factory-based fabrication such as lining materials, insulation, cladding, internal finishes, services, and doors and windows (Ross, Cartwright & Novakovic, 2006). Figure 1 (a), (b), (c), and (d), illustrates some examples of panelized wall systems.

Figure 1(a): Precast concrete wall panel

Figure 1(b): Light weight steel frame panels

Figure 1 (c): Timber frame panel (closed type)

Figure 1 (d): SIP wall erection

2.2.1 Benefits of Panelized Wall Construction

Panelized wall construction systems belong to the category of off-site modern methods of construction. Therefore, the benefits of panelized wall construction can be discussed and viewed under the benefits of off-site construction. Table 1 presents some benefits of panelized wall constructions highlighted by previous researchers.

Table 1: Benefits of Panelized Wall Construction

Benefits	Source of References
Time-saving	Li, Shen & Xue (2014); Goodier & Gibb (2007)
Quality Improvement	Venables, Barlow & Gann (2004)
Addresses skills labor shortages	Pan, Gibb &Dainty(2007); Lu & Liska (2008)
Cost saving	Pan, Gibb & Dainty (2007); Lu &Liska, (2008); Blismas, Pasquire & Gibb (2006)
Productivity improvement	Mapston & Westbrook (2010); Gibb & Isack, (2003)
Workforce drivers	Goulding, Rahimian, Arif & Sharp (2012)
Wastage reduction	WRAP (2007)

In addition to above benefits, the existing house building workforce has the ability to become qualified to produce prefabricated houses by their existing skills (Daly, 2009), while centralizing construction activities to an off-site factory would have the potential to increase their continuity and stability of employment (Goulding, Rahimian, Arif, & Sharp, 2012).

2.2.2 Barriers and Challenges in Panelized Wall Construction

The main reason for less usage of off-site in the industry is the belief that off-site is more expensive than traditional construction (Goodier & Gibb, 2007). Ting (1997) mentioned that design and construction of prefabricated buildings require high levels of collaboration among project parties, especially architects, structural engineers, and manufacturers. Similarly, Warszawski (1999) emphasized the need of an integrated system to achieve a high degree of coordination between various relevant parties that enable all functions to perform under a unified authority. Therefore, project planning and coordination are some challenges faced by the industry with panelized wall construction.

The inability to make changes onsite during construction may decrease the adoption of off-site construction techniques (Ting, 1997). Transportation restraints (PATH, 2002), Negative perceptions (O'Brien, Wakefiedand & Beliveau, 2000), and Perceived value (Craig, Laing & Edge, 2000) are identified as other challenges with panelized wall construction. Further, it is arguable that the implementation of off-site production is mainly hindered by the lack of scientific information (Trikha, 1999), and Warsawski (1999) stated an adaptation of standardization for prefabrication requires a tremendous education and training effort, which requires a substantial initial investment.

3.0 RESEARCH METHODOLOGY

A quantitative approach was mainly adopted for this research to quantify the research problem by way of generating numerical data. Initial data collection was accomplished through a literature review and a preliminary survey, followed by a structured questionnaire survey conducted with the construction professionals including engineers, project managers, architects, and quantity surveyors. This research employed the random sampling method, and the data were analyzed via Relative Importance Index (RII). About 40 questionnaires were distributed, and 31 were received with a response rate of77%. Table 2 presents the details of questionnaire response according to the professional discipline and working experience of the sample.

Table 2: Details of Questionnaire Response and Work Experience

Professional level	**No. of questionnaire**		**Response rate**	**Working experience (Years)**		
	Distributed	**Received**		**5-10**	**11-15**	**16-20**
Engineers	12	10	83.33%	2	5	3
Project managers	10	8	80.00%	-	5	3
Quantity surveyors	10	7	70.00%	2	3	2
Architects	8	6	75.00%	2	3	1
Total	**40**	**31**	**77.50%**	**06**	**16**	**09**

The open-ended questions were entered and analyzed to obtain additional results and make more meaningful interpretations. Results of the analysis are demonstrated on charts and graphs, and the tables facilitated interpretation of the findings.

4.0 RESEARCH FINDINGS

The study outcomes discussed the awareness, current practices, applicability, and characteristics of panelized wall constructions, based on the professionals' perceptions, representing engineers, project managers, quantity surveyors, and architects.

4.1 Awareness and Current practice of panelized wall construction in Sri Lanka

Respondents were asked to mention their awareness of panelized wall systems. Out of 31 respondents, 22 respondents (73.3% of total respondents) expressed their awareness about off-site panelized wall systems. Only 27% of respondents were non-informed about the panelized wall systems. Further, the current level of panelized wall systems usage and on-site wall construction methods were examined under the external and internal walls, to reveal and prove the types of wall construction methods that are popular in building projects in Sri Lanka. Respondents were given a 1-5 Likert scale, where 1 denotes 'very low' and 5 represents 'very high.'

After analyzing the respondents' opinions, the level of usage of on-site wall construction methods and panelized wall systems for external walls were illustrated in Figure 2. The brick wall indicates the highest level of usage (84.67%) and the second highest level of usage is specified by block wall, having a RII value of 81.33%. This proved that brick wall and block wall continues to be the prevalent wall construction methods for external walls in building projects in Sri Lanka. Figure 2 expresses that panelized wall systems produce significantly lower RII values according to the level of usage given by the respondents.

It proves the current level of usage of panelized wall systems is substantially less than on-site wall construction methods.

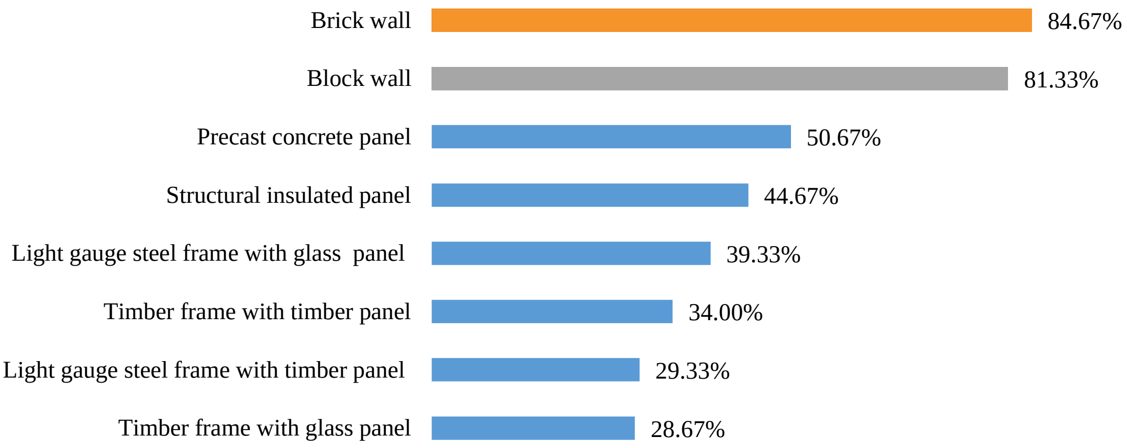

Figure 2: Level of usage of wall construction methods for external walls

Similarly, the levels of usage of wall construction methods for internal walls expressed by the respondents were analyzed. Again it revealed that block wall and brick wall are the mostly used wall construction methods for internal wall construction in building projects in Sri Lanka, of which, the level of usage for block and brick are 84 % and 83.33% respectively. It is evident that the usage of panelized wall systems for internal walls are much lesser than on-site wall construction methods. Light gauge steel frame with a glass panel with a RII value of 57.33% has the highest level of usage for internal walls among other panelized wall systems.

4.2Applicability of panelized wall construction in Sri Lanka

Respondents were asked to provide the level of applicability of panelized wall systems for external and internal walls of the buildings. The RII values for the level of applicability were obtained using the 1-5 Likert scale where 1 denotes "less applicable" and 5 represents "highly applicable."Each panelized wall system was ranked according to the significance level given by the respondents. The results are presented in Table 3.

Panelized Wall Systems	External Walls		Internal Walls	
	RII	Rank	RII	Rank
Precast concrete panel	68.0%	1	68.0%	1
Structural insulated panel	62.0%	2	45.3%	5
Light gauge steel frame with glass panel	56.7%	3	58.0%	4

Light gauge steel frame with timber panel	42.0%	4	40.7%	6
Timber frame with glass panel	39.3%	5	66.0%	2
Timber frame with timber panel	33.3%	6	58.7%	3

Table 3:
Applicability of Panelized Wall Systems for External and Internal Walls

According to Table 3, respondents believed that precast concrete panel is highly applicable for external and internal walls. It was also found that precast concrete panel is the mostly used panelized wall system for external walls whereas light gauge steel frame with glass panel is the popular panelized wall system for internal walls in Sri Lanka (refer to Section 4.1).

Further, Figure 3 illustrates the applicability of panelized wall systems according to the type of buildings as commercial, industrial, and residential buildings.

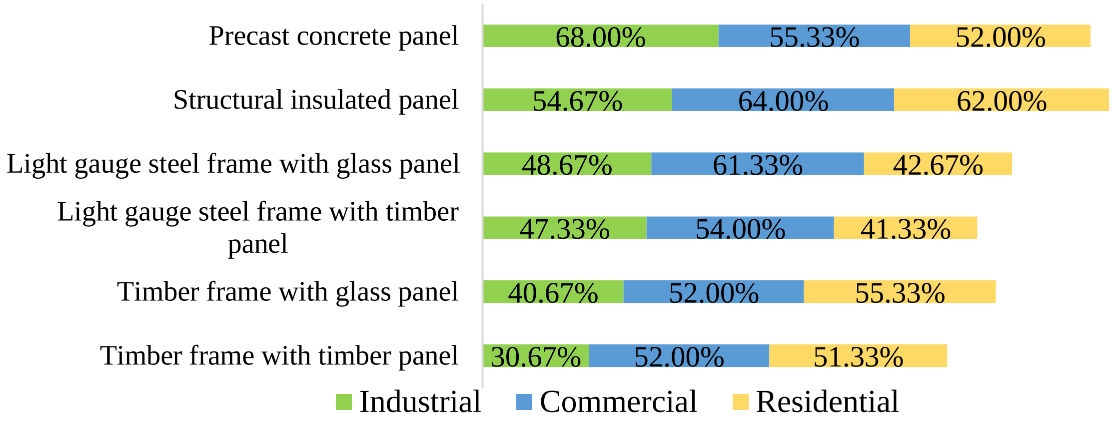

Figure 3: Applicability of panelized wall systems according to building types

As depicted in Figure 3, respondents believe that precast concrete panel (68%) is highly applicable for Industrial type building. Structural insulated panel (SIP) is identified as highly suitable for commercial (64%) and residential (62%) building types.

4.3 Characteristics of panelized wall systems and traditional methods of construction

Characteristics of panelized wall systems and traditional methods of construction are evaluated using the 1- 5 Likert scale where 1 denotes “very low” and 5 represents “very high.” Table 4summarizes the results.

Table 4: Characteristics of Panelized Wall Systems and Traditional Methods of Construction

Wall Systems	Strength	Durability	Cost	Time	Appearance	Quality	Wastage	Maintenance
Traditional Wall construction methods								
Block wall	**81.33%**	78.67%	64.67%	**80.00%**	60.67%	59.33%	61.33%	48.00%
Brick wall	78.67%	85.33%	70.00%	76.00%	60.00%	62.00%	62.00%	43.33%
Panelized Wall construction methods								
Light gauge steel frame with glass panel	51.33%	62.67%	73.33%	52.00%	**78.00%**	**73.33%**	52.00%	53.33%
Timber frame with glass panel	45.33%	53.33%	55.33%	60.67%	76.67%	59.33%	55.33%	68.00%
Structural insulated panel	78.67%	74.67%	70.67%	62.00%	76.67%	66.00%	48.67%	58.67%
Precast concrete panel	**81.33%**	**83.33%**	70.67%	60.00%	65.33%	62.67%	37.33%	42.67%
Light gauge steel frame with timber panel	62.67%	59.33%	73.33%	62.00%	74.67%	62.00%	58.67%	69.33%
Timber frame with timber panel	52.00%	55.33%	**76.67%**	**76.00%**	76.00%	65.33%	**62.67%**	**76.67%**

Referring to Table 4, light gauge steel frame with glass panel has the highest appearance (final finishing), and quality. Timber frame with glass panel received low results concerning the strength, durability, cost, and quality. In contrast, precast concrete panel and structural insulated panel were identified as high strength, durability, less wastage, and less maintenance. Respondents believed that cost, time consumption, wastage, and maintenance, are high in a timber frame with timber panel.

When panelized wall systems were compared with traditional methods of construction, the strength and durability, the levels of precast concrete panel, and structural insulated panel were similar to traditional methods of construction. Also, it revealed that wastage and time consumption of panelized wall systems were lesser than traditional methods of construction, except in the timber frame with timber panel, which shows higher wastage and time consumption than traditional methods of construction.

4.4 Key advantages and disadvantages of panelized wall systems

Respondents were asked to express their level of agreement with the pros and cons of panelized wall systems compared to on-site wall construction methods. After calculating the RII value for each advantage, the values were ranked from largest to the smallest value. It helped to recognize the key factors which received higher significance by the respondents. Similarly, main disadvantages were perceived as barriers to the implementation and development of panelized wall construction in Sri Lanka as presented in Table 5. RII value of each is presented within parenthesis.

Table 5: Key advantages and disadvantages of panelized wall systems

Key advantages	Key disadvantages
• Decreasing construction duration (74%)	• Lack of awareness (80.0%)
• Addressing skill labor shortage (71.3%)	• Client resistance (80.7%)
• Increased quality (70.0%)	• Lack of guidance (80.7%)
• More consistent product (68.7%)	• Less personal experience of use (75.3%)
• Reduce construction waste (68%)	• Insufficient worker skills (75.3%)
• Improve work place safety (67.3%)	• Increased risk (74%)
• Improve energy efficiency (67.3%)	• Non-availability in local industry (68%)
• Reduce defects (64.7%)	• Negative image (65.3%)

4.5 Future demand of panelized wall systems

Respondents were asked to express their perception of the future demand for panelized wall systems in Sri Lanka. Significance levels from very low (1) to very high (5) were calculated, and results are presented in Figure 4. Accordingly, precast concrete panel indicates the highest RII value of 76.67% for future demand, while Structural insulated panel (SIP) has the second highest RII value (i.e. 66%), and thus, the next higher future demand after the precast concrete panel.

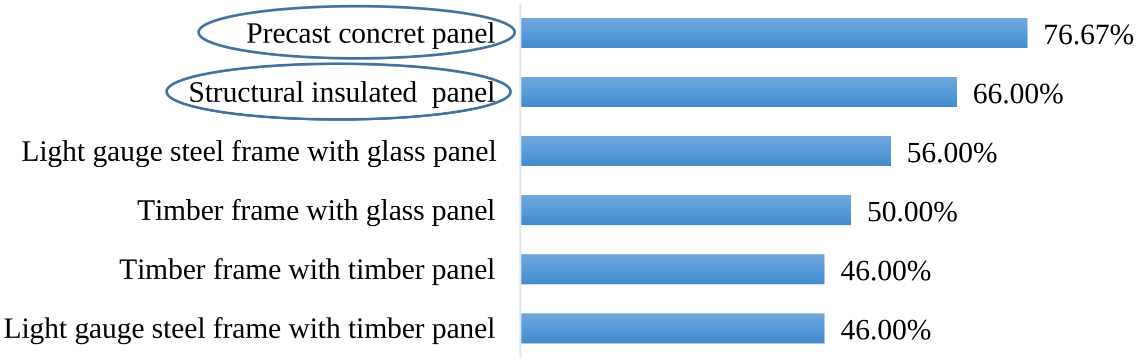

Figure 4: Future demand of panelized wall systems

It revealed that some contractors in Sri Lanka already use theprecast concrete wall panels in the building construction industry, but they are not used for wall construction of buildings in a high proportion. Use of structural insulated panelsis less in Sri Lankanbuilding construction industry, but the construction professionals have indicated a high significance level for future demand of the SIP.

Further, respondents were invited to give suggestions to establish panelized wall systems in the future. Among the questionnaire sample, nine (9) respondents emphasized industry-wide awareness programs should be conducted for the future uptake of panelized wall systems. Hence it is obvious that Sri Lankan building construction industry has to pay attention to the necessity of organizing awareness programs on panelized wall systems.

Six (6) respondents commented about the greater necessity of proving quality standards of panelized wall systems should comply with the codes to establish panelized wall systems in building projects in Sri Lanka. Another five (5) respondents highlighted the importance of taking appropriate measures to reduce the cost factor of panelized wall systems without compromising the quality. What they emphasized was that the production cost of panelized wall systems is to be minimized while ensuring the quality, is not compromised.

Four (4) respondents pointed out that highly specialized knowledge in production is required for the future uptake of panelized wall systems. They stated that panelized wall systems have to be produced under the expertise knowledge compliance with codes. Another four (4) respondents expressed that panelized wall systems shall consider the ratings for buildability of contractors, conducted by the construction industry development authority (CIDA), while three (3) respondents feel that panelized wall systems should be included under CIDA specifications and standards.

5.0 CONCLUSIONS

Panelized wall construction is the process where wall panels are manufactured under the factory conditions according to the requirements and transported to the site for assemble into a three-dimensional structure or to fit within an existing structure. The precast concrete panel is the mostly used panelized wall system in Sri Lanka when compared to other five panelized wall systems.It revealed that the majority of construction professionals are aware ofpanelized wall systemsdespite its less usage andlower popularity among customers.

The paper addresses current usage and applicability of panelized systems regarding building types, and identifies the key advantages and disadvantages of panelized wall systems against on-site wall construction. The key advantages of panelized wall construction are the reduced construction duration, providing a solution for skilled labor shortage, and increase quality. The major disadvantages of panelized wall construction are the lack of awareness, client resistance, and absence of guidance.

The paper discusses the level of future demand for the panelized wall systems. Accordingly, the precast concrete panel has the highest future demand among panelized wall systems followed by a structural insulated panel. Respondents believe that panelized wall systems can be used as an innovative solution to deal with inherent issues in traditional methods of construction and improve the efficiency and sustainability in the building construction sector, as it has many benefits over the conventional on-site construction.

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IMPACT OF ICTAD PRICE ADJUSTMENT FORMULA FOR PRICE VARIATIONS IN CONSTRUCTION PROJECTS

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ABSTRACT

The cost estimation prepared during the bidding stage may not be same as the cost calculated at the time of actual work done. This is because of open market escalation of construction inputs. To address this problem, ICTAD has introduced a country-specific document "ICTAD formula method for adjustments to contract price due to fluctuation in prices". Price Fluctuation Formula mainly considers several parts; value of work done for a particular period, non-adjustable work elements, cost of materials at site, percentage input contribution from each construction inputs and price indices variation compared to the start of the project, which needs careful attention.

This research mainly focused on the effect of ICTAD price adjustment formula to recover the actual material cost of the contract. To fulfill this, research aimed at finding the relationship between ICTAD price adjustment and true price adjustments through the data analysis and estimating accuracy. Also, research focused on evaluating the suitability of using unique price indices for the price fluctuation adjustment based on the ICTAD formula method.

To fulfill above objectives, analysis was carried out referring different variables in the formula under for the data gathered from 11 actual projects which are already completed and prices of sand, aggregate, rubble and bricks were collected from January 2015 to August 2016 covering twenty districts in Sri Lanka.

Base on the results, main findings are; excluding non-adjustable elements in the formula does not affect the actual cost recovery, use of material cost at site which is not still used for the construction is having some effects, use of same input percentages throughout the project may lead to getting higher price adjustment and use of unique price indices are not suitable.

***Keywords**: ICTAD Price Adjustment, Price indices, Input percentage, non - adjustable element.*

1. INTRODUCTION

It is obvious that many construction projects last for a long duration. Also, the time of preparation of the tender, time of awarding the tender and the time of completion of the project has a significant difference. Due to the price fluctuation of materials, equipment, labors, etc., bid amount for a particular project can be varied from the actual construction cost. Also, repercussions for the construction industry such as high contractor's bid that includes a cushion may lead to uncompetitive bids (Jayasinghe et al. 2015). Figure 1 shows how price fluctuation has affected to the construction industry.

To address this problem, Institute for Construction Training and Development (ICTAD) (Now it is called as CIDA) has introduced a procedure for price adjustment due to price variations of materials, equipment, labor hours, etc. ICTAD is the responsible authority for the construction works related activities in Sri Lanka. So they have developed a general formula for adjustments to contract price due to fluctuation in prices. In this research, it is expected to study the effect of ICTAD price fluctuation formula procedure.

This research is aiming to study whether the available ICTAD price adjustment procedure is exactly suitable to use with the present format.

This aim was achieved through identifying the relationship between ICTAD price adjustment and true price adjustments through the data analysis and evaluating material price variations compared to indices variation

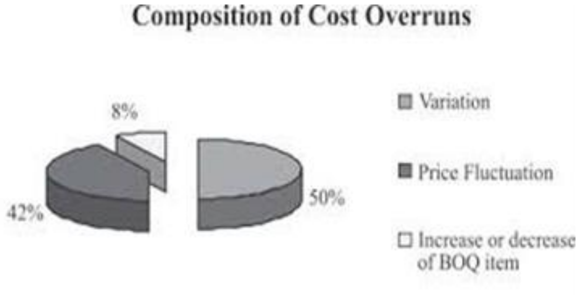

Figure 1: Composition of Cost Overruns (Zainudeen et al., 2008)

2. LITERATURE REVIEW

ICTAD formula is a "country-specific" approach with the aim to provide a reasonable basis for calculating price adjustments due to open market escalation in specified construction inputs such as major building materials, hire charges of plants and wages for the labor. The choice of those inputs largely depends on the principle of cost significance in the overall share of the quoted tender price. Adjustments to the contract price shall be made in respect of not only in the rise but also in fall in the cost of materials and other inputs affecting the cost of execution of works (Jayalath 2014).

Price Adjustment clauses for a particular contract allow the contractor to submit a more realistic bid without adding an arbitrary markup for escalation. Price escalation is the change in cost or price of specific goods or services in a given economy over a period. The escalation in the price of units reflects the inflationary trends in the economy (Chaphalkaretal & Sandbhor 2012, cited in Jayasinghe et al. 2015). A brief overview of the practice of fluctuation adjustment in other countries, confirms that there is no single fluctuation formula that suits all jurisdictions, nor a single formula to satisfy all employers and contractors (Construction industry Council 2011, cited in Jayasinghe et al. 2015).

Even though some researchers argue that the ICTAD Price adjustment formula is a compensation method and not to recover the full actual cost (Jayalath 2014), ICTAD introduced Formula method for reimbursement of price fluctuation of materials, labor and equipment in construction project in 1993. ICTAD Price fluctuation formula can be divided into two parts; contracts exceeding Rs.10 million and contracts not exceeding Rs.10 million. The price indices for materials, labor, machinery and fuel are published by the ICTAD every month.

The Formula method for contracts exceeding Rs.10 million.

$$\mathrm{F} = \frac{0.966(\mathrm{V} - \mathrm{V_{na}})}{100} \sum_{\text{all inputs}} \mathrm{P_{x.}} \frac{(\mathrm{I_{xc}} - \mathrm{I_{xb}})}{\mathrm{I_{xb}}}$$

The Formula method for contracts not exceeding Rs.10 million

$$\mathrm{F} = 0.869(\mathrm{V} - \mathrm{V_{na}}) * \frac{(\mathrm{I_{tc}} - \mathrm{I_{tb}})}{\mathrm{I_{tb}}}$$

F = Price adjustment for the period
I_{xb} = Base index for input X, published by ICTAD
I_{xc} = Current index for input X
P_x = Percentage cost contribution of input X
V = Valuation of work done during the period concerned including 80% of cost of materials at site
V_{na}= Value of net non-adjustable element
I_{tc}= Current composite index for the type of work published by ICTAD
I_{tb}= Base composite index for the type of work published by ICTAD

3. RESEARCH METHODOLOGY

The research was conducted in two parts. Cost data for 11 projects were collected to find the relationship between ICTAD formula procedure and true price variation. Material prices were collected covering the time period from January 2015 to August 2016 for twenty districts.

4. RESULTS AND DISCUSSION

The collected data were analyzed considering different aspects and results are as follows.

1. Effect of Non- adjustable elements

Usually, non-adjustable elements are identified at the tender documents preparation stage and those non-adjustable elements are entered as contract data. Careful selection of non-adjustable elements will not affect the contractor's price fluctuations. This statement was proved using data taken from all the projects and data for project 1 is plotted in Figure 2.

Figure 2 shows the percentage variation of price indices for the months of interim bills (current indices) and percentage variation of price adjustments for those interim bills for values obtained for project number 1.

Price indices are published by ICTAD for every month in their monthly bulletin. Variations of price indices were calculated considering the base indices which are relevant to one month prior to the bid closing month of that particular project. In Figure 2, percentage variation of price adjustment to work done and percentage price adjustment to work done without non-adjustable elements are marked. All the other lines represent percentage variation of indices for different construction inputs

In here it can be seen that the price adjustment variation without considering non-adjustable elements and variation of current indices are with the same pattern. But price adjustment to the work done and variation of current indices are not in the same pattern

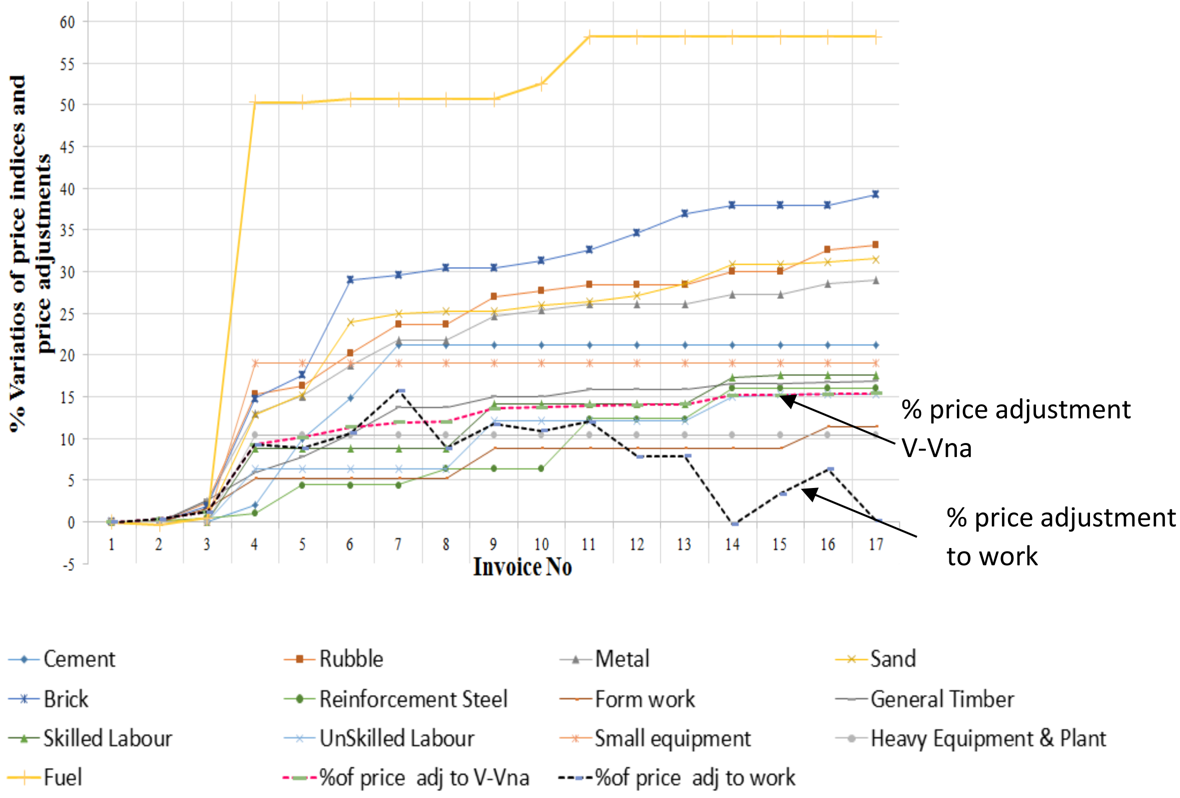

Figure 2: Relationship between current indices and price adjustment for Project 1

2.Effect of current indices related to the materials which are not used during a particular valuation period

Valuation data analysis graph of selected project is shown in Figure 3. Similar to Figure 2, in Figure 3 also price adjustments variations are labeled. Other lines indicate the percentage variations of indices.

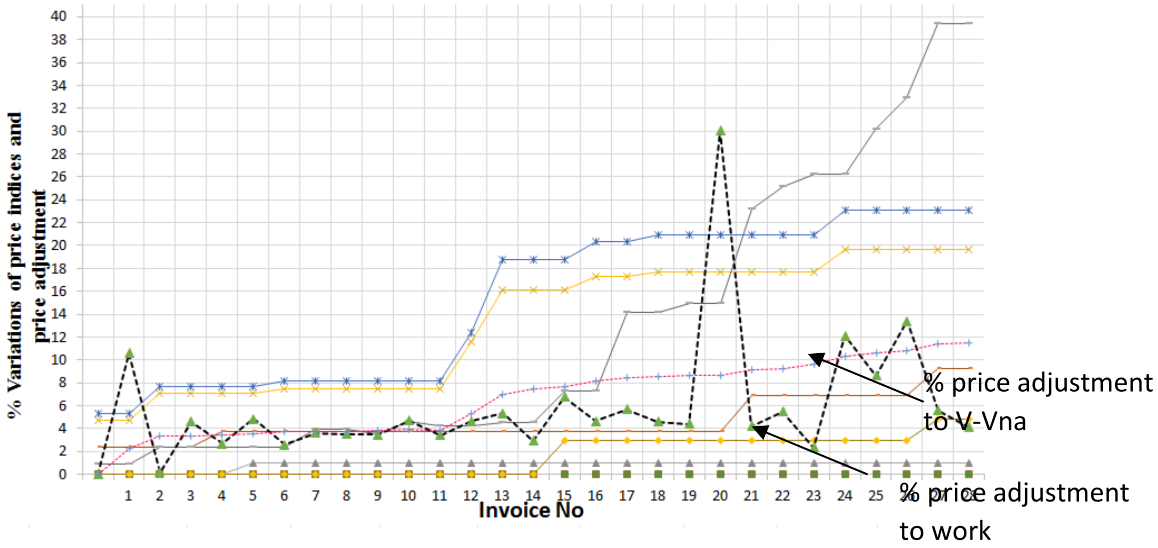

Figure 3: Relationship between current indices and price adjustment for Project 2

In this project also, current indices' variation increase throughout the project. When considering the invoice numbers 2, 20 and 24, price adjustment percentage is high. By considering the project details, it can be identified that some current indices are not used during the valuation period, but those current indices are used for the price adjustment calculation. Because of that, Factor sum [Px (lxc-lxb)/Ixb] increases for low work done value for the valuation period. Because of this reason the client has to pay extra price adjustment value for the contractor for less work done. So, in here another shortcoming of the ICTAD price fluctuation formula is, current indices which are not used at the time of valuation are considered for price fluctuation calculation.

3. Effect of selecting Input percentage

Valuation data analysis graph of project No 3 is shown in Figure 4.

Current indices and price adjustments increased throughout the project. After data analyzing and plotting project valuation data, some relationship between current indices variation and price adjustment variation were identified. Below Table 1 shows the input percentage and current indices variation for machinery and fuel. Although the machinery has lower value in percentage of current indices variation, it contribution to price adjustment is high as its input percentage is high.

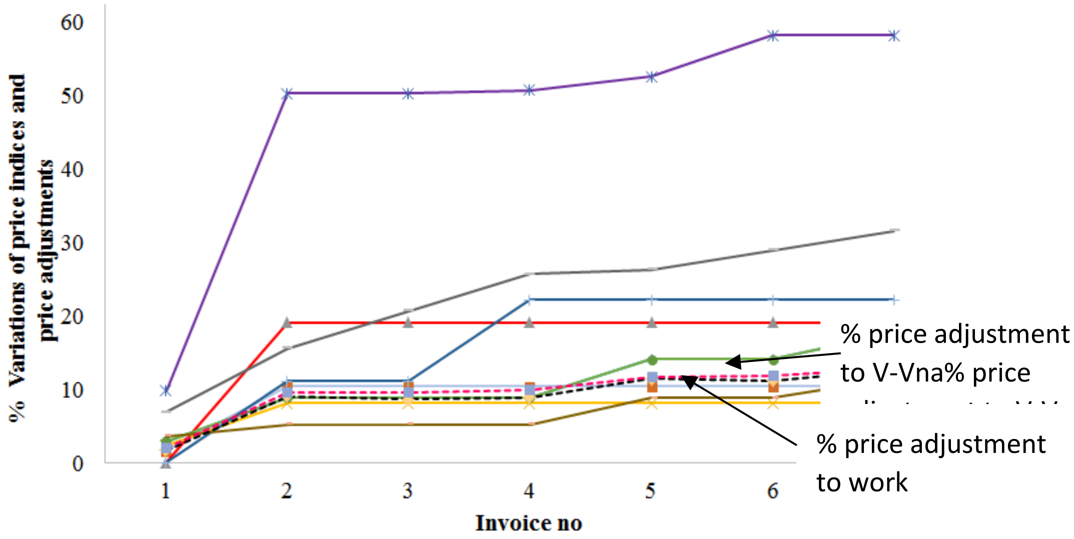

Figure 4: Relationship between current indices and price adjustment for Project 3

Table 1: Price adjustment data of Bill No 2 under Figure 3

Input name	Input %	Current index variation	Factor of sum
Fuel	3%	50.32%	1.51
Machinery	41%	10.41%	4.57

4. Cost of Materials at the site

According to the Figure 5, for invoice numbers 8 and 17, price adjustment is relatively high. This is because of the cost of materials at site. That information is shown in Table 2

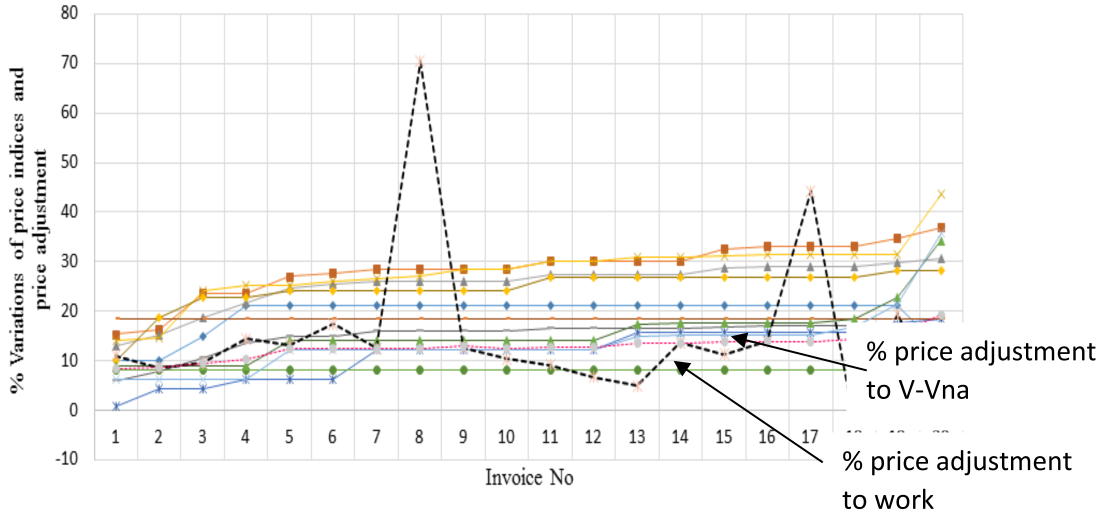

Figure 5: Relationship between current indices and price adjustment for Project 4

Table 2: Cost of Material for project under Figure 4

Bill No	7	8	17	18
Cost of Materials (Rs.)	8,128,740	21,912,262	24,265,415	8,423,358

This shows the cost of materials at the site effects to price adjustments.

ICTAD price indices were used to compare the true material price variation. The research assumed that the price indices are based on the prices of materials, equipment, labor, etc. in the Colombo district, it was the base for comparison. To prove this assumption, first material price variation pattern in Colombo and the indices variation pattern was checked for sand, rubble aggregates and bricks. Figure 6 shows actual price variation of sand in Colombo and indices variation which proved the assumption.

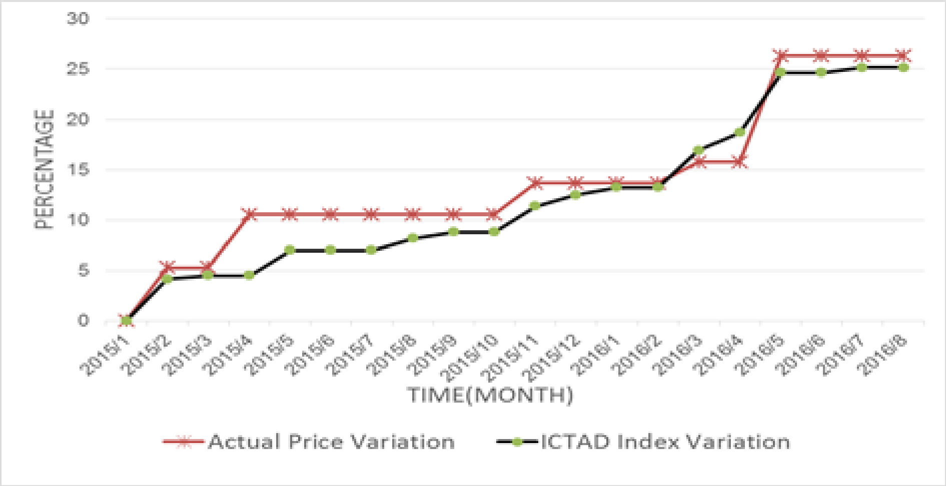

Figure 6: Graph of price variation and indices variation of sand in Colombo district

The correlation coefficient of these two variations was 0.95. When considering that, there is similar behavior of the variations, graphically and statically for both indices and actual price of sand.

A similar analysis was carried out for aggregates, bricks and rubble. For those materials also Colombo price variation and relevant indices variation were in similar pattern both graphically and statistically.

Then the analysis was done to check the variation in other district. Figure 7 shows variation of sand prices in different districts and variation of indices. In Figure 7, the first month (January 2015) material prices were considered as the base and for other month price variation was calculated as a percentage, and for Indices, January 2015 index was considered as the base and indices variation for other months were calculated as a percentage.

The Same procedure was adopted to see the variation for aggregates, clay bricks and rubble and similar results were obtained.

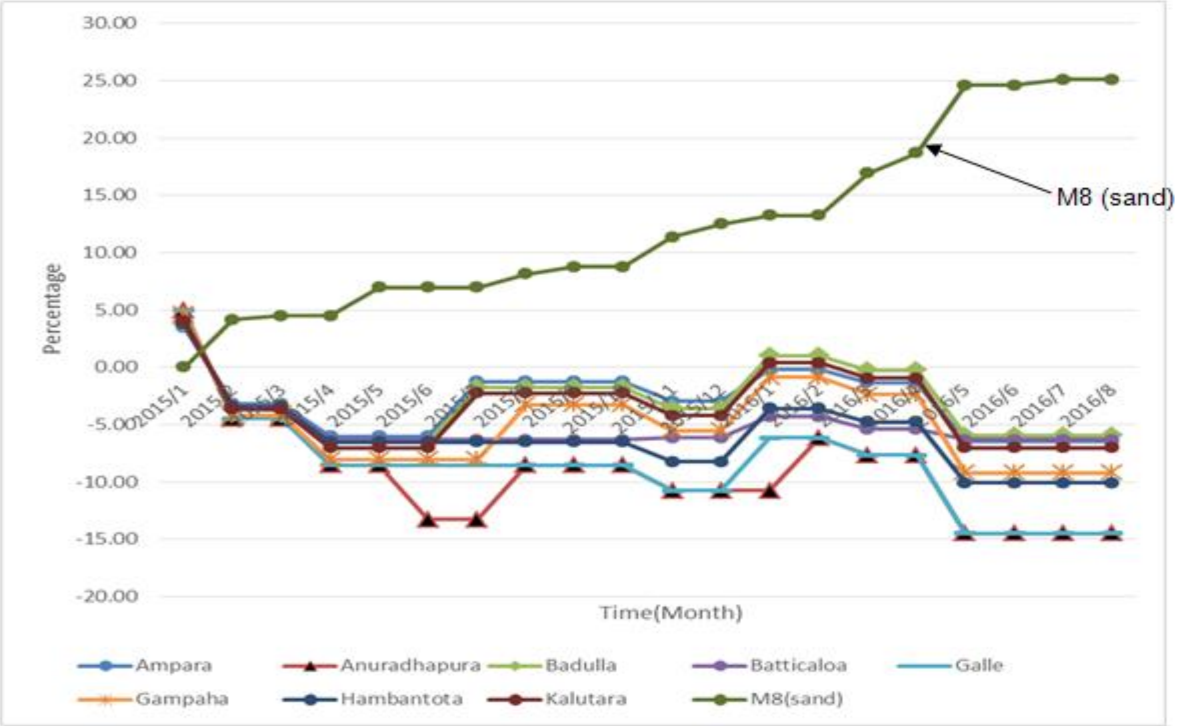

Figure 7: Graph of actual and ICTAD price variation of sand

5. CONCLUSIONS

Based on the above-explained results, price adjustment calculation without non-adjustable elements is fair. Use of current indices & their input percentages defined at the beginning, for all the valuation period is not fair. Suggestion to that effect is to check the price adjustment using indices which are related to the materials used during the valuation period. Similarly, use of same input percentage values is not fair. Suggestion for that effect is Input percentages can be calculated considering the materials used during the valuation period and not the entire project. Also, adding the cost of materials at site to work done leads to higher price adjustment. So, eliminating that part that effect can be minimized.

Variation of prices of construction inputs during a contract period is not avoidable. Since material price differs from place to place, use of unique formula or unique indices leads to an unfair price adjustment to the client or contractor. This research aimed to clarify that un-similar behavior of price fluctuation.

During this research, it was identified the behavior of price fluctuation for selected materials in Colombo district and variation of price indices published by ICTAD. Based on analyzed data, it can be clearly seen that the price indices calculation procedure may be based on the available prices for construction inputs in Colombo region. Then for the other district, Colombo was taken as the base and price variations were calculated. Based on the above-mentioned analysis results it is very clear that the price indices variation pattern and actual price variation patterns in other district except Colombo are not similar and it was proven by graphically and statically. Therefore the use of same indices for projects in anywhere in the country may cause to lose to the contractor or to the client.

So through this research, it was identified the use of unique indices is not suitable. To overcome this problem, ICTAD may publish a separate set of indices for different district. It may cause to make the project management complex, but fair payment to the contractor can be achieved. Or else price adjustment formula can be modified by incorporating some additional factors depending on the applicable district.

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ASSESSMENT ON HAND ARM VIBRATION EXPOSURES OF OPERATORS IN CIVIL ENGINEERING CONSTRUCTION INDUSTRY

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ABSTRACT

Hand arm vibration of operators in construction industry is inevitable although the exposure could be reduced by proper assessments and controlling methods. A long term exposure of arms to high vibration levels could cause vibration induced syndromes.

Objective of this research study is to evaluate the vibration exposure levels which transfer through the human arm to the human body while engaging in civil engineering construction activities. Ten operators in civil engineering construction sites were selected as a study group. A questionnaire survey was conducted with the operators to identify whether they have diagnosed with hand arm vibration syndromes, their experiences and age. Vibration exposure levels transferred through the arms to the human body were measured using a vibration meter (SV 106) with a mounting tri axial accelerometer. It was found that operators were not aware about the vibration related syndromes, although they were exposed to the excessive vibration. Measured exposure levels were evaluated based on the standards, ISO 5349-1(2001). Vibration exposure level which transfer to the human body has decreased considerably while working with wearing a pair of gloves.

Keywords: *Hand arm vibration, vibration syndromes. Tri axial vibration meter*

1. INTRODUCTION

Most of civil engineering construction activities have involved exposure to vibration with the source come from power tools, and industrial machineries. Operators exposure to hand arm vibration are inevitable in some of the civil engineering construction activities including drilling, breaking, compacting. Also the apparatus used to build, create, and explore have used more energy, as a result, increased quantities of energy have been dissipated in the form of vibration, some of which has been transmitted to people through human body part that directly touched to the vibrator source. This is caused to some health hazards in the human body (Mansfield, [1]).

Human body vibration can be divided into two main categories: Hand arm vibration (HAV) and the Whole body vibration (WBV). Hand arm vibration is transmitted through the handles or surface of the work piece, via palms, and the fingers into the hands and arms while workers engage in the hand held or manually guided machines. Examples of machines that may cause hand-arm vibration are demolition hammers, drills, hammer drills, angle grinders, chain saws and hand-held circular saws.

Workers, who frequently exposed to this HAV, may suffer from hand arm vibration syndrome (HAVS). The period of time between exposure to HAV and development of symptoms is varied, ranging from months to years (Griffin, [2]). Workers who exposed to hand arm vibration often suffered with white finger effect, which causes neurological and motor disorders in the hands and fingers (Nakamura et al, [3]). Risk of HAV caused by the use of such equipment is preventable, but once the damage is done, it is permanent (Anon, [4]).

It has been reported that there are different corollary about the syndrome, but patients who are having HAVS are most commonly described as having neurological, vascular and musculoskeletal symptoms and signs such as disturbed sensation (numbness, tingling), cold intolerance, episodic finger blanching, pain and weakness in hands and arms (Buhaug, et al. [5]).

Objective of this study is to assess hand arm vibration exposure levels of operators in construction industry. In addition, effect of wearing a pair of glove on reducing the vibration was investigated.

2. METHODOLOGY

A questionnaire survey and vibration exposure measurements were conducted simultaneously. Selected construction sites were visited with the permission of responsible parties. Suitable safety procedures were followed.

2.1. Study group

Ten hand arm vibration related machine male operators were selected as a study group. These ten operators consist with two jack hammer operators, four plate compactor operators and four drilling machine operators. The operators, who participated for this study, were within the age range of 20 -40 years.

2.2. Questionnaire survey

Questionnaire survey was conducted for each operator to investigate their health levels and current situation of their profession. In addition, their work experience and age were recorded.

2.3. Instrument

A vibration meter, SVANTEK 106, was used as an instrument to measure the exposure levels of hand arm vibration which transfer to the human body. Vibration meter was calibrated according to ISO 2631-1 [6] and ISO 5349-2 [7] to measure both frequency weighted HAV exposure levels in three orthogonal directions: x axis, y axis and z axis (Figure 1).

2.4. Measuring exposure levels.

Measuring parameters such as start delay time, measurement duration, weighting factors for each axis was set into the vibration meter (SVANTEK 106) before commencement of recording exposure levels. After selecting appropriate operator to measure the exposure levels of the HAV via the vibration meter, the hand sensor was mounted (Figure 2(a)) following defined coordinate system (Figure 1).

The orthogonal which belongs to hand arm vibration measurements are based on the head of the third metacarpal. The x-axis is through the palm, the y-axis is across the palm towards the thumb, and the z-axis extends towards the fingers parallel with the back of the hand (Figure 1). Above definition of coordinate system has an advantage that is no confusion regarding axes for palm or power grips or any orientation of the hand (ISO 2631-1 [6])

Operator was instructed to work usually assigned task and vibration exposures were measured (Figure 2(b)). The coordinate system which was indicated on the instrument should exactly follow the above defined coordinate system (Figure 1).

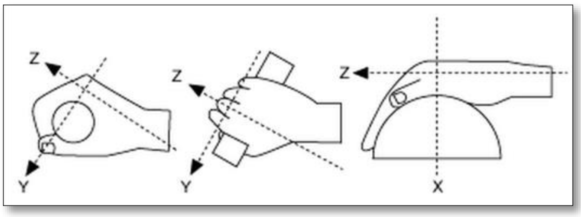

Figure 1: Defined Coordinate system for
Hand arm vibration measurements

Figure 2: Measuring procedure of hand arm vibration exposures

(a) Sensor was placed on the hand

One operator from each category of equipment was instructed to wear a pair of gloves and allow him to work, while the vibration exposures which transfer to his arm with the gloves were measured.

2.5 Specification of Glove

The pair of gloves used in the current study (Figure 3) is a general purpose cotton glove available in Sri Lanka market. It is anatomically shaped to provide a good fit and has a cotton liner to provide better comfort.

Figure 3: A pair of gloves that used for the experiment

2.6 Analysis

Frequency-weighted hand-transmitted vibration (a_{hw}) for each direction was obtained from SV 106 analyser. Human exposure to hand arm vibration was evaluated by referring the guidelines for measuring and evaluating human exposure (ISO 5349-1(2001) and ISO 5349-2 (2001)).

However, according to the ISO 5349-1 standard recommendations, the most important parameter used to describe the magnitude of the vibrations transmitted to the operator's hands is the root-mean square (rms) frequency-weighted acceleration, expressed in m/s^{-2}. The vibration total value, a_{hv}, or Frequency-weighted acceleration total value was determined as defined in Equation (1)(ISO 5349-1,2 [7]).

$$ah_v = \sqrt{ahw_x{}^2 + ahw_y{}^2 + ahw_z{}^2} \text{ ---------- } (1)$$

Where ahw_x, ahw_y and ahw_z are frequency-weighted acceleration values for the single axis

Vibration exposure not only depends on the magnitude of the vibration total value, also depends on the duration of the exposure. Total time for which the hands are subjected to vibration during working day (Daily exposure duration) has been expressed in terms of Frequency-weighted acceleration total value as shown in Equation (2) (ISO 5349-1,2 [7]).

$$A(8) = ah_v \sqrt{\frac{T}{T_o}} \text{ ------------ } (2)$$

Where T is the total daily duration of the exposure in seconds, and T_o is the reference duration of 8 hours (28800 s)

HAV daily exposure action value (EAV) of 2.5 ms^{-2} , and HAV daily exposure limit value (EAV) of 5.0 ms^{-2} were considered.

3. RESULTS AND DISCUSSION

3.1 Questionnaire survey

Results of the questionnaire survey are summarised in Table 1. It seems that operators' age and the working experience affect on the operator's health issues (Table 1). Jack hammer operator, OP1, who has a 15 years of work experience is affected by the pain and weakness in hands. Jack hammer operator, OP2, who has 23 years of experience, has numbness. Among the drilling machine operators, OP6 has considerable work experience (i.e., 20 years), felt pain and weakness in hands. In addition, plate compacter operator, OP 7, OP 8 and OP 10, felt uncomfortable while operating drilling machine.

3.2. Vibration exposure levels

Frequency-weighted-hand transmitted vibration (a_{hw}) for each direction was obtained from SV 106 analyser. Figure 4 shows frequency-weighted hand-transmitted vibration (a_{hw}) for x, y and z directions of the drilling machine operator, OP3.

Frequency-weighted acceleration total value was obtained according to Equation (1) and is shown in Figure 5. Table 2 summarises Frequency-weighted hand-arm vibration exposures (A_{hw}) for each direction, calculated Frequency-weighted acceleration total value (Ah_v) 8-hour exposure value, A(8) for operators in three different vibratory equipment. Eight-hour energy-equivalent frequency-weighted acceleration, A(8) for OP3,OP4 and OP6 are greater than the exposure limiting values. However, A(8) value of OP5 (i.e., 2.44 ms^{-2}) is just below the exposure action value (2.5 ms^{-2}).

Table 1: Age, work experience, exposure duration and health issue of ten operators

Equipment	**Operator**	**Age (yrs)**	**Work Experience (yrs)**	**Exposure duration (hrs)**	**Health Issue**
Jack Hammer	OP 1	45	15	8	Pain and weakness in hands
	OP 2	42	23	8	Numbness
Drilling Machine	OP 3	31	4	6	No
	OP 4	29	6	5	No
	OP 5	35	8	6	No
	OP 6	48	20	6	Pain and weakness in hands
Plate Compactor	OP 7	34	9	8	Normal daily tidiness
	OP 8	42	13	7	tingling
	OP 9	26	2	8	No
	OP 10	40	12	8	Pain and weakness in hands

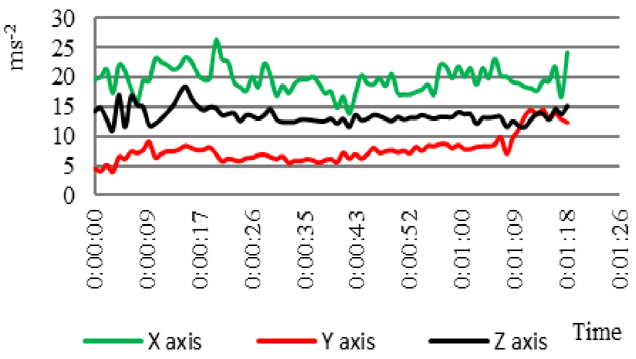

Figure 4: a_w variation of exposure levels of a drilling machine operator, OP3

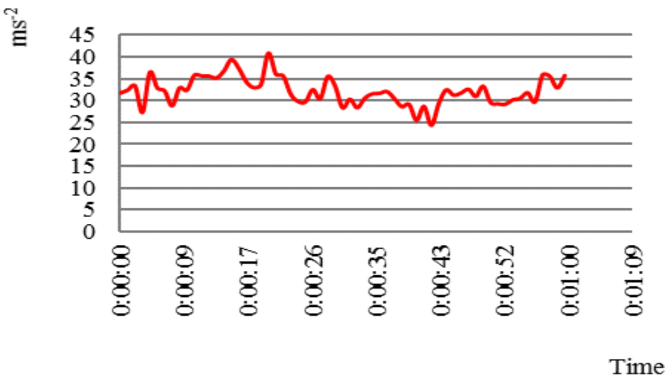

Figure 5: Frequency-weighted acceleration total value for a drilling machine operator, OP3

Generally, vibration exposure in *x* axis was greater than the other two directions (Figure 4). It was found that the maximum vibration level induced in *z* axis is 18.66ms^{-2}. For both *y* axis and *x* axis maximum vibration level is 15.63 ms^{-2}. Maximum vibration exposure levels were observed from the plate compactor operators, OP 9 and OP10. It seems that more than 90% of hand arm vibration related equipment generates higher vibration exposure (Table 2) which exceeded the exposure limiting values of legislations: ISO 5349 (2001)

Table 2: Ahw$_x$, Ahw$_y$, Ahw$_y$, Ahv and A(8) values for all operators

Equipment	Operator	Ahw$_x$ (ms^{-2})	Ahw$_y$ (ms^{-2})	Ahw$_z$ (ms^{-2})	Ah$_v$ (ms^{-2})	A(8) (ms^{-2})
Jack Hammer	OP1	4.85	6.63	1.97	13.96	13.96
	OP2	2.11	3.18	9.60	9.86	9.86
Drilling Machine	OP3	7.45	11.18	11.18	24.09	20.86
	OP4	7.21	13.81	6.86	17.03	13.46
	OP5	2.53	1.19	0.32	2.81	2.44
	OP6	8.00	5.76	16.06	22.12	19.15
Plate Compactor	OP7	2.50	5.76	5.76	8.52	8.52
	OP8	6.79	9.87	9.63	15.3	14.38
	OP9	8.91	4.21	18.66	21.01	21.01
	OP10	15.63	15.63	16.08	25.25	25.25

Figure 6 shows the Frequency-weighted acceleration total value (Ahv) work with gloves and the work without wearing the gloves for the operator,OP3.Vibration exposure decreased considerably while working wearing gloves. However, it has been observed that wearing gloves was not practice in civil engineering construction industry, letting operators in health risk.

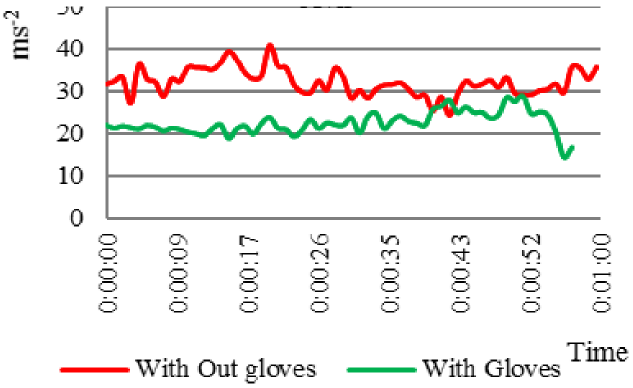

Figure 6: Comparison of Ahv values obtained at two different conditions: with wearing gloves and without wearing gloves

4.0 CONCLUSIONS

More than 90% of hand arm vibration related equipment generates higher vibration exposure which exceeds the exposure limiting values of legislations: ISO 5349:2001. Majority of operators, who have more work experience and exposure to the higher vibration level, have felt tingling, pain and weaknesses in hand. Vibration exposure level which transfers to the human body decreases considerably when operators are working with wearing a pair of gloves, indicating that operators risk on hand-arm-vibration syndrome could be reduced by practicing of wearing gloves when operating vibrating tools in civil engineering construction industry. Further studies are recommended for investigation on effects of types of gloves on exposure levels of hand-arm-vibration prevailing in industry.

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VARIATION OF MECHANICAL PROPERTIES AND LOAD CARRYING CAPACITIES OF REINFORCING STEEL BARS USED IN SRI LANKA

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ABSTRACT:

Steel reinforcement bars are an important part in reinforced concrete structures. Mechanical properties such as yield strength, tensile strength and elongation are the most important parameters of steel reinforcement bars for structural designs. The variation of these parameters causes a variation in the load carrying capacities of them. Therefore, a study was carried out to investigate the variation of the mechanical properties and the load carrying capacities of steel reinforcement bars used in Sri Lanka. More than 300 specimens of Quenched and Self-Tempered steel (QST), Cold Twisted Deformed steel (CTD) and plan Mild Steel (MS) bars with diameter in the range 6 mm – 32 mm were subjected to tensile test. The results showed considerable differences in the mechanical properties and load carrying capacities compared to the BS 4449 standard. The major finding is that the characteristic yield strength of RB 500 bars is less than the specified characteristic value of 500 N/mm^2.

Keywords: Reinforcement steel, Mechanical properties, Load carrying capacity, Structural design.

1 INTRODUCTION

Reinforcing steel is described as the steel product with circular or practically circular cross section which is suitable for the reinforcement of concrete (BS 4449, 2005). Three types of reinforcing steel products used in Sri Lanka are Cold Twisted – Deformed (CTD) high yield steel bars, Quenched and Self-Tempered (QST) steel bars and Mild Steel (MS) plain bars and coils. The yield strength (*Re*) of CTD steel is 460 N/mm^2 (steel grade 460) and that of MS is 250 N/mm^2 (steel grade 250) (BS 4449, 1997). *Re*of QST steel is 500 N/mm^2 (steel grade 500) (BS 4449, 2005). QST steel bars are the common steel reinforcement product used today as the main reinforcement bar for reinforced concrete.

The steel reinforcement in concrete structural members should be capable of carrying tensile loads. For the analysis of reinforced concrete sections, the design strength for reinforced steel is derived from the characteristic strength (i.e., the yield strength, f_y) divided by the partial safety factor for strength of materials (γ_m) which is 1.05 (BS 8110 - 1, 1997). This shows that the safety allowance given for the strength of steel is only 5%. Therefore, the allowable strength reduction of reinforcing steel bars should be within this 5% limit (maximum of 5%). The most used reinforced concrete design code in Sri Lanka: BS 8110 – 1, 1997 assumes the bilinear stress – strain behaviour for reinforcing steel with Young's modulus (E) of 200 kN/mm^{2}as shown in Figure 1. Therefore, the stress – strain behaviour of steel reinforcement bars used in the country should satisfy this behaviour.

There are many manufacturers who produce reinforcing steel bars to the construction market in Sri Lanka. However, due to lack of research on reinforcing steel used in the country, there are no details available on variation of mechanical properties of reinforcing steel. The mechanical properties given in design codes (BS 8110 – 1, 1997) are directly used in reinforced concrete designs in the country assuming that they are same as those given in design codes. Therefore, the present study was carried outto investigate the mechanical properties of reinforcing steel used in the country and to compare them with the codes. It was expected that the findings of the study may produce important information for structural engineers in the country on actual mechanical properties of reinforcing steelused in Sri Lanka.

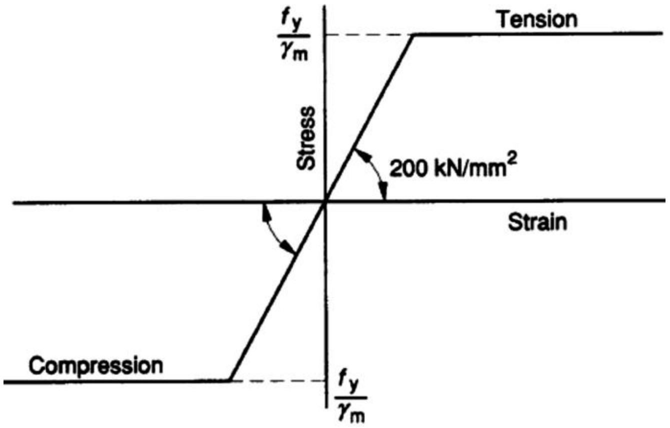


Figure 1: Bilinear behavior of reinforcing steel (BS 8110 – 1, 1997).

2 STANDARD SPECIFICATIONS FOR REINFORCING STEEL

The standard specifications of the Sri Lanka Standards Institute –SLS (SLS 375, 2009), are used for maintaining the quality of steel reinforcement in Sri Lanka. The SLS standards have been derived from British Standards such as BS 4449, 2005 for QST steel bars (grade 500), BS 4449, 1997 for MS plain bars and coils (grade 250) and CTD steel bars (grade 460), BS 4482, 2005 for steel wires and BS 4483, 2005 for steel reinforcement fabrics. The main focus of the present study is comparing the quality of reinforcing steel used in the country with BS 4449, 1997 and BS 4449, 2005 standards.

As per BS 4449, 2005, grade 500 steel has been subdivided into three ductility categories; B500A, B500B and B500C. BS 4449, 1997 shows two ductility categories for grade 460 steel bars as 460A and 460B. The characteristic tensile properties of thesteel grades are given in Table 1. Both BS 4449, 2005 and BS 4449, 1997 define the characteristic values of all steel grades as the lower or upper limits of the statistical tolerance interval at which there is a 90% probability that 95% of the values are at or above the lower limit or there is a 90% probability that 95% of the values are at or above the upper limit respectively.

The density and cross section dimensions are important parameters of reinforcing steel bars for determining *Re* and *Rm* (tensile strength). The density of all grades of steel is specified as 78.5 kN/m^3 and specifies that the mass and cross sectional area (and bar diameter) of reinforcing steel bars should be calculated using this density value (BS 4449, 1997, BS 4449, 2005). The permissible deviation from nominal mass per meter length for QST steel bars is 4.5% (BS 4449, 2005). The maximum allowable deviation for cross sectional dimensions of CTD and MS plain bars is 8% from the nominal dimension (BS 4449, 1997).

According to BS 4449, 1997 and BS 4449, 2005, the long term quality level of reinforcing steel should be determined from Eq. (1);

$$\bar{x} - k(SD) \geq Cv \qquad (1)$$

where, $\bar{x}$ is the average value (mean value), SD is the standard deviation of the population, *Cv* is the characteristic value and *k* is a coefficient (the acceptability index) which is a function of the number of test results (i.e. samples tested) for a reliable failure rate of 5% at a probability of 90%. The coefficient *k* needed to determine *Re* and *Rm* varies in the range from 1.71 (for 1000 samples) to 3.4 (for 5 samples). *k*for other properties such as strength ratio (*Rm/Re*) and cross sectional area is in the range from 1.34 (for 1000 samples) to 2.74 (for 5 samples).

Table 1: Characteristic tensile properties of reinforcement steel, BS 4449, 2005 and BS 4449, 1997

Grade / Ductility category	**Yield strength *Re* (N/mm^2)**	**Tensile/Yield strength ratio *Rm/Re***	**Elongation at maximum force (%)**
B500A	500	1.05	2.5
B500B	500	1.08	5.0
B500C	500	>1.15,<1.35	7.5
460A	460	1.05	2.5
460B	460	1.08	5.0
250	250	1.15	-
Maximum permissible *Re* value for grade 500 steel bars is 650 N/mm^2.			

3 METHODOLOGY

The summary of the methodology used to investigate the variation of strength and related parameters of reinforcing steel bars is as follows.

- Steel reinforcement bars (QST, CTD and MS plain bars and coils of diameter in the range from 6 mm to 32 mm) produced by several manufacturers and widely used in Sri Lanka was subjected to testing.
- The steel designation marked on the reinforcement bars, the patterns of ribs and *Rm/Re*values were used to identify the steel grade (BS 4449, 2005, BS 4449, 1997).
- The mechanical properties of reinforcing steel were determined experimentally as per BS EN 10002 – 1, 1990.

- Experimental mechanical properties were statistically analyzed and then compared with the values specified by the codes and relevant statistical analyses were carried out as per BS 4449, 2005 and BS 4449, 1997.
- The comparisons of these experimental data and values specified in the codes were used to reach the conclusions of the study.

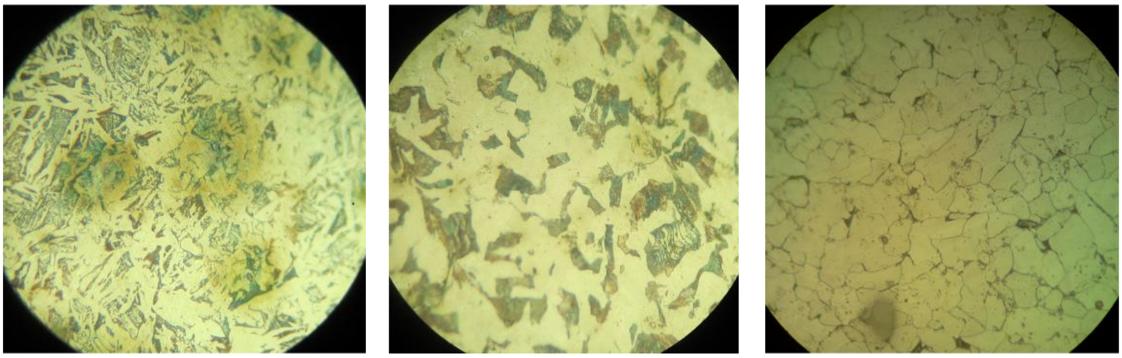
4 RESULTS AND DISCUSSION

4.1 Comparison of QST steel, CTD steel and MS bars

QST steel bars are the most used steel bars in Sri Lanka at present. The reason is the high strength and quick production process than CTD steel bars. However, CTD steel bars are still used in small quantities. MS plain bars are used very rarely for specified purposes; however MS coils are frequently used as shear links (stirrups).

Microstructure of a metal depends on its production process. Therefore, microscopically observations are useful to identify metals that are produced under different processes. The ferrite – perlite grain structure with clear grain boundaries of low carbon MS, well separated and mostly equal grains (having more dark grains than MS)of medium carbon CTD steel and the unique microstructure of QST steel due to the quenching and tempering process are shown in Figure 2.

Stress – strain relationship for QST steel, CTD steel and MS is another important relationship. The visible yield zone before strain hardening and elongation in MS, strain hardening without any yield signs in CTD steel (due to cold twisting and related plastic strain) and recognizable yielding before strain hardening in QST steel are the features of these stress – strain relationships.



(a) (b) (c)

Figure 2: Microstructure (1000X) of (a) QST steel, (b) CTD steel and (c) MS

Mechanical properties of QST steel, CTD steel and, MS plain bars and coils of different diameter tested as mentioned in Section 3 are compared. Table 2 gives a comparison of *Re*, *Rm*, *Rm/Re* and standard deviations (SD) for QST, CTD steel bars and, MS plain bars and coils. It was observed that the mean value and SD of *Re* for tested QST specimens were 551 N/mm^2 and 32.6 N/mm^2 respectively. The mean value and SD of *Re*for CTD specimens were 483 N/mm^2 and 7.9 N/mm^{2}and those for MS bars were 326 N/mm^2 and 62.7 N/mm^{2}respectively. Statistical analysis of experimental results showed that the *Re*of experimental results for QST steel and MS are less than the expected characteristic *Re* valueswhile *Re* of experimental results for CTD steel is satisfactory (Note: Refer to Eq. (1)). The experimental *Re* values for QST steel, CTD steel and MS were 493 N/mm^2, 463 N/mm^2 and 188 N/mm^2 respectively.

Table 2: Strength properties of QST steel, CTD steel and, MS plain bars and coils

Category	**QST**	**CTD**	**MS**
Nominal bar diameter	All sizes	All sizes	All sizes

No. of specimens tested	289	10	19
Yield strength *Re*(N/mm^2)	551	483	326
SD of yield strength (N/mm^2)	32.6	7.9	62.7
Ultimate tensile strength *Rm* (N/mm^2)	646	576	469
SD of ultimate tensile strength (Nmm^2)	35.3	9.7	50.6
Stress Ratio	1.17	1.19	1.47
SD of Stress Ratio	0.03	0.02	0.20

4.2QST steel bars

Due to its large use, QST steel bars were given a high importancein this study and the test results are further discussed here. Figure 3 (a) shows the rib pattern of QST steel bars used in Sri Lanka that is similar to grade RB500B (Figure 3 (b)). However, based on *Re/Rm* as shown in Figure 4, it was observed that most of the specimens tested belongto grade RB500C category, but the rib pattern is different. RB500C steel has the highest ductility ratio (1.15 <*Re/Rm*< 1.35) which is favorable for reinforced concrete structures.

(a) (b) (c)

Figure 3: (a) Rib pattern of QST steel bars used in Sri Lanka, (b) rib pattern of RB500B and (c) rib pattern of RB500C steel bars (BS 4449, 2005)

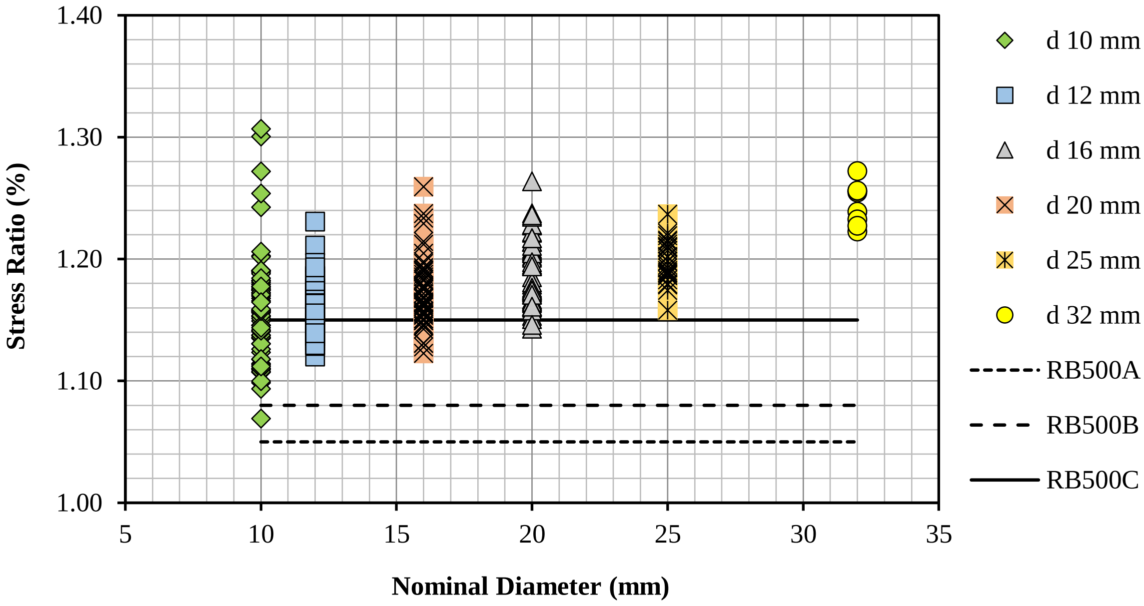


Figure 4: Stress ratios of QST bars with different bar diameters compared with different ductility categories. Most of the experimental results verify that the QST bars tested are of grade RB500C category. (Note: d is the nominal bar diameter)

Test results indicated considerable variations of strength parametersas given in Table 3. QST bars of diameters from 10 mm to 32 mm show a mean *Re* varying between 562 N/mm^2 – 523 N/mm^2 indicating a high mean *Re* for small diameter bars. Other than the difference of the characteristic strength discussed in Section 4.1, it was observed that (Figure 5) there are considerable number of test results fallen below the permitted minimum value of *Re*of 485 N/mm^2. (Note: BS 4449, 2005 indicates that any test results should not fall below the minimum value).

The experimental mean *Rm* value of QST bars lies in the range 637 N/mm^2 – 652 N/mm^2. The *Rm* values of all the specimens tested were greater than the permitted lower limit of *Rm* (i.e., 515 N/mm^2, Figure 6).

Table 3: Variation of mechanical properties of QST steel bars with different diameter.

Nominal bar diameter (mm)	**10**	**12**	**16**	**20**	**25**	**32**
No. of specimens tested	72	67	58	55	29	8
Mean yield load (kN)	44	63	112	168	264	420
SD of yield load (kN)	2.8	3.4	5.7	10.3	17.4	31.0
Yield strength *Re* (N/mm^2)	562	555	557	536	539	523
SD of yield strength (N/mm^2)	36	30	28	33	35	39
Mean Ultimate load (kN)	51	73	131	200	317	523
SD of ultimate load (kN)	5.5	4.2	6.0	10.2	19.6	35.6
Ultimate tensile strength *Rm* (N/mm^2)	652	643	653	637	645	651
SD of ultimate tensile strength (Nmm^2)	37	37	30	32	40	44

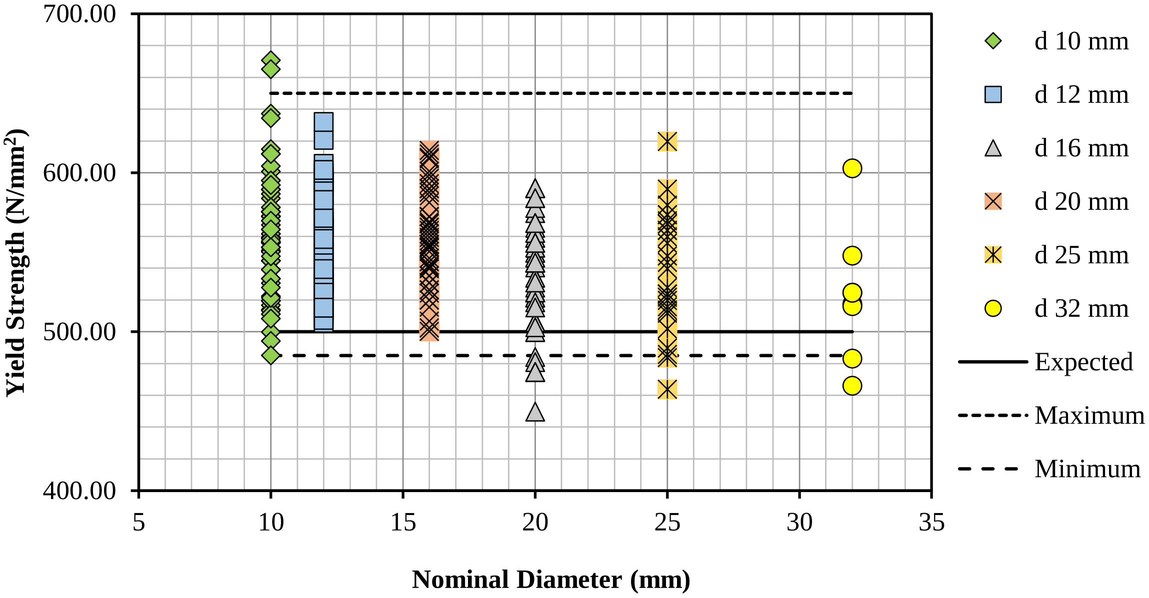


Figure 5: Variation of *Re* of QST bars with different bar diameters. (Note: “Expected” denotes the expected characteristic value of *Re*. “Maximum” and “Minimum” denote the permitted maximum and minimum *Re* values respectively).(Note: d is the nominal bar diameter)

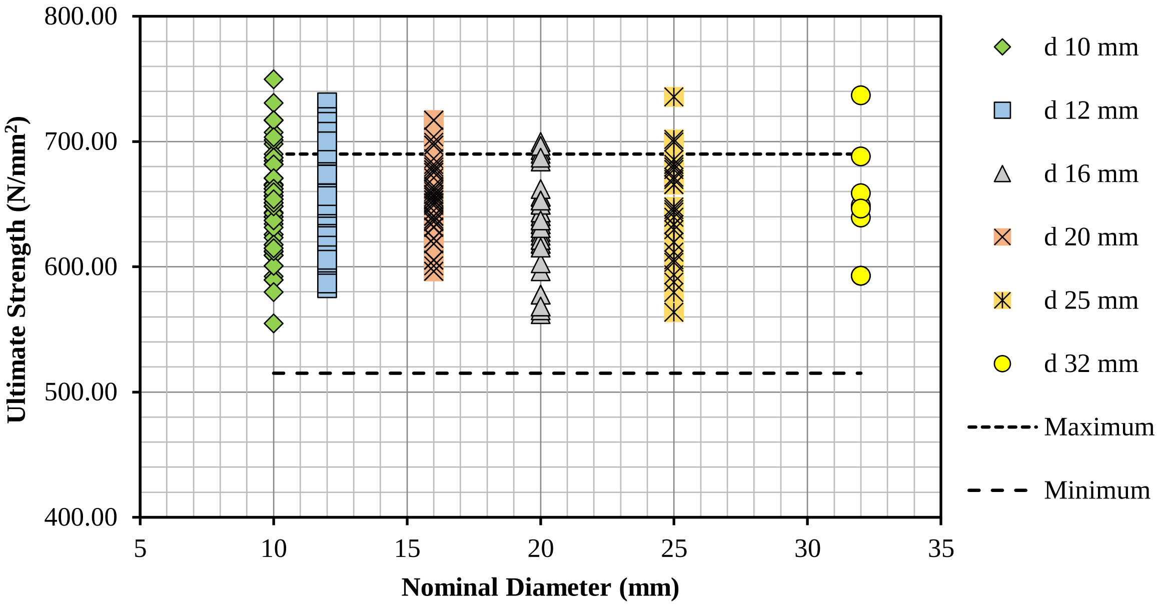


Figure 6: Variation of *Rm* of QST bars with different bar diameters. (Note: “Maximum” and “Minimum” denote the permitted maximum and minimum *Rm* values respectively).(Note: d is the nominal bar diameter)

The variation of the mass of QST bars was then investigated. It was observed that there was considerable number of specimens falling below the permitted minimum values of the mass as shown in Figure 7. Mass (kg per meter length) is the parameter used to determine the effective cross sectional area (and hence the effective diameter) of reinforcement bars (BS 4449, 2005). Therefore, low mass of reinforcement bars eventually gives a low cross section area. The important fact to mention here is that the low cross section area provides high yield strengths even if the yield load is low. This fact was observed in most of the specimens with low mass. On the other hand, in reinforced concrete designs, the reinforcement steel is indicated (in drawings) as number of bars assuming a certain capacity for reinforcement bars based on the nominal bar diameter. Therefore, the carrying capacity of reinforcement bars is even more important than the *Re* value that depends on the mass. Therefore, in this study, the variation of yield load was also investigated.The mean yield loads and SD of QST steel bars with different diameters are given in Table 3.Figure 8shows the experimental characteristic yield load capacities of QST steel bars (using Eq. (1)) and the expected characteristic yield load capacities estimated using the nominal diameter and characteristic *Re* of 500 N/mm^2. It also shows the minimum yield load capacity estimated using the minimum permitted diameter (0.94*nominal diameter) and the permitted minimum*Re* (485 N/mm^2) and, the maximum yield load capacity estimated using the nominal diameter and the permitted maximum *Re* (650 N/mm^2).

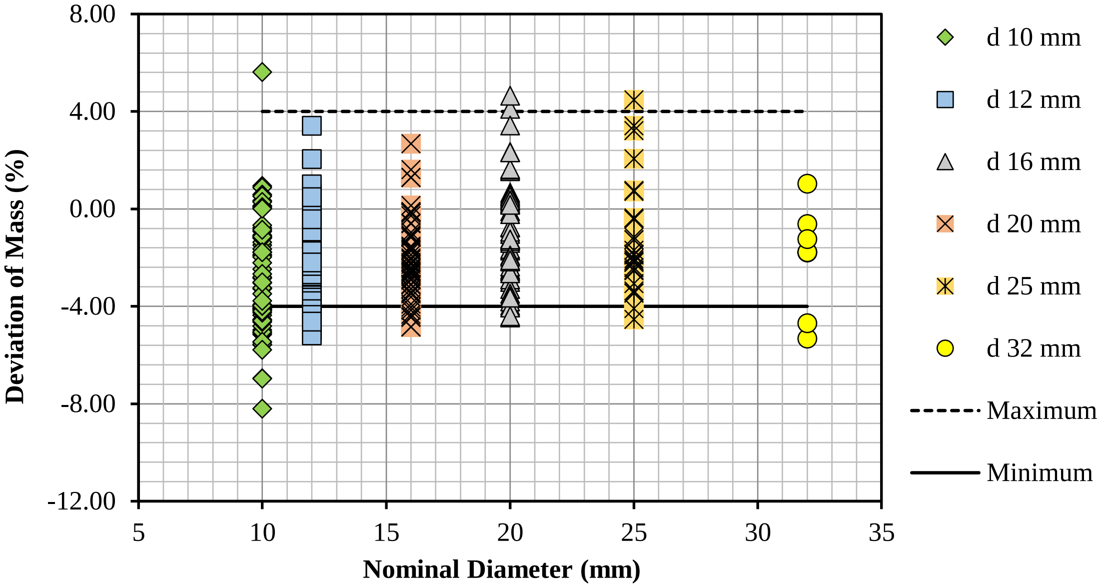


Figure 7: Variation of mass of QST steel bars against the permitted minimum and maximum values.(Note: d is the nominal bar diameter)

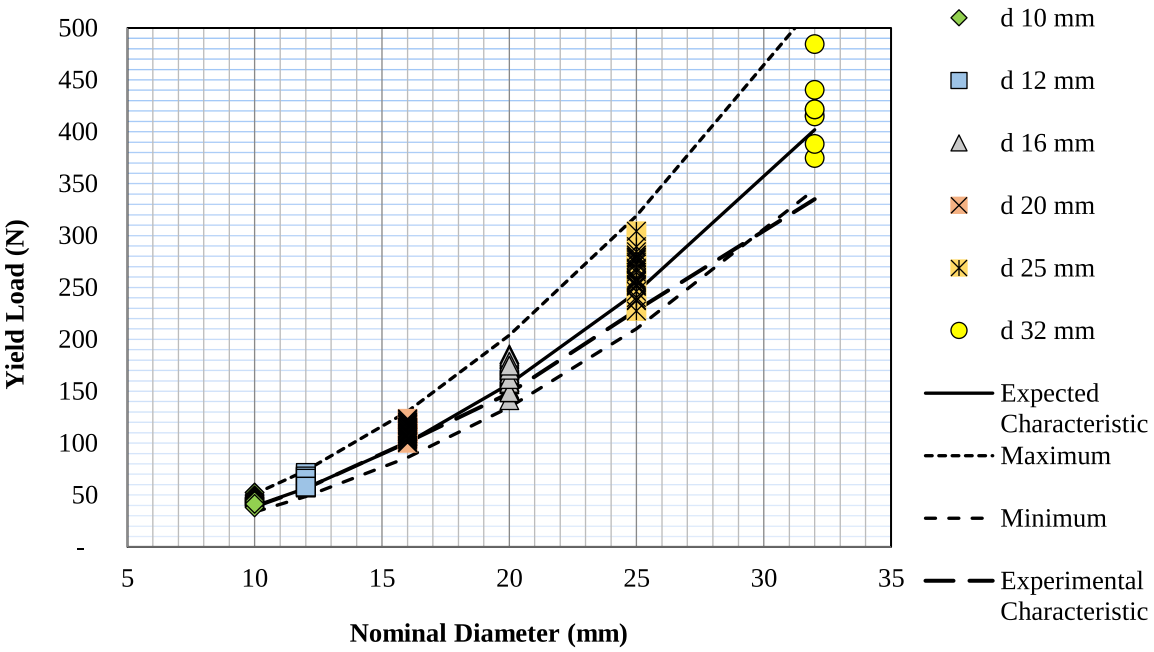


Figure 8: Variation of yield load carrying capacity of QST steel bars with different bar diameters (Note: “Expected Characteristic” denotes the yield load calculated from characteristic *Re*. “Experimental Characteristic” represents the experimentalmean – k(SD). “Minimum” and “Maximum” denote the permitted maximum and minimum loads respectively).(Note: d is the nominal bar diameter)

The most important finding is that the experimental characteristic yield loads of QST steel bars are less than the expected characteristic yield loads. However, as shown in Figure 8, the experimental characteristic yield loads of QST bars are above the minimum required yield loads except 32 mm diameter bars. Therefore, in reinforced concrete designs, the characteristic yield load of a QST steel bar should not be estimated using the nominal diameter and the *Re* of 500 N/mm^2 that gives a higher value than the actual. The recommendation based on the experimental results is to use the values given in Table 3.

5 CONCLUSIONS

This experimental study was carried out to provide the mechanical properties of QST steel, CTD steel and MS bars and, load carrying capacities of QST steel bars used in Sri Lanka for reinforced concrete structures. The conclusions stated here were reached based on the statistical analysis of the experimental results.

- The experimental characteristic value of *Re* of QST steel bars (493 N/mm^2) is less than the characteristic *Re* value specified in the standards (500 N/mm^2). Further, there were number of specimens fallen below the minimum *Re*value (485 N/mm^2).

- The experimentalcharacteristic *Re*values of different diameter QST steel bars were different. High characteristic*Re* values were observed for small diameter bars and vice-versa. The experimental characteristic *Re* (Eq. (1), for 95% probability) of 10 mm, 12 mm and 16 mm diameter QST steel bars are in the range of 494 N/mm^2 – 503 N/mm^2 while that of 20 mm and 25 mm diameter bars lies in the range 465 N/mm^2 – 472 N/mm^2.

- Experimental characteristic yield load capacities of QST steel bars are lower than the expected characteristic yield load capacities, but higher than the minimum permitted yield load capacities except for 32 mm diameter bars. It is recommended that the yield loads of QST bars should be estimated from the statistical data obtained from experiments (given in Table 3).

- Based on the stress ratio (*Rm/Re*) and rib pattern it was observed that most of the QST steel bars used in Sri Lanka belong to RB500C strength and ductility category.

- Experimental characteristic *Re* value of CTD steel bars are in line with the characteristic *Re* value specified in standards (460 N/mm^2: BS 4449, 1997).

- Experimental characteristic *Re*value of MS bars is significantly less than the characteristic *Re* value specified in standards (188 N/mm^2 against 250 N/mm^2: BS 4449, 1997).

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A COST PLANNING FRAMEWORK FOR THE BUILDING CONSTRUCTION PROJECTS IN SRILANKA

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ABSTRACT

The construction industry of a country will play an important role in the economic growth of that country being an industry that is large, dynamic and complex. This is true for a country like Sri Lankaas well. In the construction sector, a project will be considered as a success if it has met the goals and objectives stated in its project plan and if it has attained the expected technical performance by completing the work on schedule within the budgetary allocations provided. Among all project parameters, cost has become the most important, being the prime factor contributing to the success of a project. Most of the construction projects in Sri Lanka incur cost overruns. Therefore, the ability to minimize the cost of a project could determine its profitability and even the very survival of the company undertaking the project. Therefore, this research was aimed at investigating the existing cost planning practices in Sri Lanka in order to propose a cost planning framework suitable for the construction industry in the country.

Considering the research aim, it was decided to use the qualitative approach in this research. A literature synthesis and expert interviews were conducted as the first step towards achieving the research aim that focused on cost planning practices in the construction industry in Sri Lanka. In order to collect the data, thirteen semi-structured interviews were conducted among Chartered Quantity Surveyors who have had experience by working in the construction industry in Sri Lanka. NVIVO software package was used to analyze the collected data in order to identify the existing practices, drawbacks of the existing system and the probable solutions. A framework for cost planning practices in the pre-construction stage was finally developed in accordance with the RIBA Plan of Work. Finally, the suitability of the New Rules of Measurement technique was determined and a cost planning framework with some of exclusions was proposed to use in the construction industry in Sri Lanka.

Keywords: *Cost Planning, Cost Overrun, Construction Industry, Sri Lanka*

1.0.INTRODUCTION

The construction industry of a country is a major contributor to the economic growth of that country (Chan, 2009). Construction involves engineering projects, building new structures and renovations to existing buildings that involve additions, alterations, or maintenance and repairs(Behm, 2008). The success of any project would depend on how it achieves its goals and objectives in its project plan and also its expected technical performance by completing the work on schedule within the budgetary allocations provided. However, out of all the project parameters relating to time, cost and quality, project cost has become the most important parameter since it is the prime factor that contributes to the success of a project (Elhag et al, 2005). Cost management is all about achieving value for money and it involves overall planning, co-ordination, control and reporting of all cost related aspects of a project from its initiation to its maintenance (Benge, 2014). Cost planning is the most significant factor to be considered in planning a project as otherwise it could lead the project to incur cost overruns. Ferry and Brandon in a study of Kirkham (2014) has identified cost planning as a process which is difficult to define concisely as it involves a variety of procedures and techniques. However, cost planning in new projects will depend on the availability of accurate and well-documented information related to the anticipated costs. Cost analysis is the process of analyzing and recording the cost data of projects once the relevant information has been received (Peter & David, 1980).This cost analysis has to be prepared soon after the bids have been received considering a number of reasons such as the currency of the cost information, familiarity with the project etc.(Cartlidge, 2013).As Cartlidge (2013) further mentioned, the data used for the cost analysis is required to be adjusted before using them in the cost plan as they are related to price levels, quantity and quality.

Most of the construction projects in Sri Lanka, especially building construction projects, suffer from cost overruns which have been identified as one of the major contributory factors for project terminations. The root cause of cost overruns is poor cost planning and cost management during the pre-contract stage. Nine out of ten projects (90%) in the construction industry in Sri Lanka have been affected by cost overruns, and 20% of building projects among them have been affected by cost overruns beyond 30% of their contract sums. Even though some cost planning methods are already being used in the construction industry, they are not being done properly (Wijekoon and Attanayake, 2013). When industry needs and the research gap are considered, it is revealed that there is a very high need for research on cost planning. Therefore, the aim of this research was to investigate the cost planning practices which are currently being followed in Sri Lanka in order to propose a suitable cost planning framework for the construction industry in Sri Lanka.

2.0.LITERATURE REVIEW

2.1 Cost Planning in Building Construction Projects

For the successful execution of a project, effective planning often becomes essential. As a result of inadequate planning, many projects of varying sizes end up with undesirable results such as structural failures, cost overruns and issues related to litigation. The professional advisor of a construction project has an obligation to ensure that his client receives the best value for his money (The Australian Institute of Quantity Surveyors, 2001). Cost planning of building projects is one of the crucial factors that help to fulfill this obligation. According to Bathurst and Butler (1973), cost planning is a term used to describe any system of bringing cost advice to bear upon the design process.

As Seeley(1996) stated, cost planning is a systematic application of cost criteria to the building design process in order to maintain sensible and economic relations among different project parameters (cost, time, quality and functionality) in the first phase of a project and to maintain overall control of the proposed expenditure in the second phase of the project as circumstances dictate. Several contemporary authors including Ashworth (2004), Ashworth and Hogg (2007), Kirkham(2007),Smith and Jaggar (2007) and Ashworth(2006) have expressed that cost planning is not only a pre-tender estimating method but that it also seeks to offer a control mechanism during the design stage. Since buildings with widely varying characteristics perform a diversity of functions in order to serve the needs of a variety of building clients, their erection is subject to different administrative and contractual arrangements and thus there can be no universal method of cost planning which can be readily applied to any building project irrespective of its type (Seeley, 1996).

There are two methods of cost planning which are most commonly used in the construction industry such as elemental cost planning (elemental target cost planning) and comparative cost planning (Seeley, 1996).In elemental cost planning, the cost target of the building is determined by the client himself or jointly by the architect and the quantity surveyor of the project. Most commonly, sketch plans are done and thereafter the cost target is determined by using an approximate method. Then, the total amount of money is distributed among the major elements of the building using the cost analysis of a previously erected building. A plan is prepared for each of the elements and the cost will be expressed per square meter of floor area. The sum of the costs of the elements should not exceed the total estimated cost (Ashworth, 2006). Although the comparative method does not seek to enforce rigid cost limits on the design of particular elements, it provides flexibility to choose a combination of possible design solutions that will serve the purpose. The objective of comparative cost planning is to ensure economy by investigating sections of the design and presenting a range of alternatives for various elements, all of which will satisfy the requirements of the client's brief in terms of function, construction and specification (Bathurst and Butler, 1973).

2.2 Stages Involved in the Application of the Cost Plan

Clients want cost and time certainty starting from the earliest stage of a project. Thus, cost planning will apply essentially throughout the stages involving the brief, sketch plans and working drawings (Akintoye, 2000)which are indicated below:

- Brief - estimating or establishing the target cost
- Sketch plans- cost planning
- Working drawings-cost checking

During the inception stage, the client's requirements are identified and the client appoints an architect. During the feasibility stage, an effective cost control mechanism is established and the cost planner has to look out for the critical cost implications in the brief. The cost target of the project can be worked out by using approximate estimating methods. Alternatively, the cost target may be established by the client to suit his budget (Gunner, 1997). As Gunner and Skitmore (1999) mentioned, a brief is completed and the full design of the project is developed in the scheme design stage. As Gunner and Skitmore (1999) further stated, the cost plan will be prepared element-wise and the cost expressed per square meter of the floor area in order to compare with other types of designs. It will clearly indicate how the design team proposes to distribute the overall cost among the major elements of the building. Throughout the detailed design stage, the cost plan is utilized to check the cost of the building. The architect will have to perform the detailed designing of the building during this stage by keeping costs within the framework of the cost plan. The approximate quantities method is the most suitable and accurate estimating technique that can be used to check costs when detailed specifications and drawings are available(Gunner, 1997).However, the success of an estimation will largely depend on the accurate integration of project information, resources, and control, with project implementation (Park and Papadopoulou, 2012).

Therefore for successful cost management , among other tasks, the data of the project in-hand has to be readily available along with data from previous projects available in a database containing historical data (Shane et al., 2009). In the cost analysis domain, access to historical data is of special interest for decision makers since relevant past information can be shared with the project to be estimated in respect of information related to its design, process, data, and knowledge (Cho, 2013). Moreover, historical cost data will show how successful the business had been in the past. The current information tells where the business stands at present; and the past and present information collectively would help to position the business for the future. Therefore, the maintenance of records of cost analysis data will be necessary to facilitate accurate cost estimation.

In forecasting and control activities, cost data has to supplement the numbers, areas, and volumes etc., which have been used to describe the building (Elhag et al, 2005). A typical quantity surveyor will use cost information for the four (04) main purposes (Ferry and Brandon, 1991) indicated below.

- Controlling and monitoring of a contract for which a contractor has already been selected through interim and final account procedures
- Estimating the future cost of a project and the controlling of the design to ensure that the cost quoted is closed to the tendered figure
- Balancing costs in a cost plan to ensure that money is spent within the client's budget

- Negotiating rates with a contractor towards moving a contract quickly

2.3 Cost Overrun

The description of the cost overrun by Zhu and Lin (as cited in Enshassi, Al-Najjar and Kumaraswamy, 2009) and Avots (1983)as the discrepancy between the original cost and the cost at completion has become so common that a special term, “cost growth” is being commonly used with reference to that. The degree of cost overrun can be compared by measuring the change in the contract amount divided by the original contract amount.

$$\textbf{Cost overrun} = \frac{\textbf{Final contract amount} - \textbf{Original contract amount}}{\textbf{Original contract amount}}$$

According to Jackson (as cited in Enshassi, Al-Najjar and Kumaraswamy, 2009), this calculation can be altered to indicate a percentage. The cost overrun can also be defined as an occurrence in which it has been claimed that the provision of contracted goods or services has required more financial resources than was initially agreed upon between the project client and the contractor (Nega, 2008). Hence, cost overrun is a very common phenomenon in any construction project. It is a frequent phenomenon in Sri Lanka too and is common in most of the projects in the local construction industry. Various standards and methods are used in the construction industry for cost estimating purposes as described later.

2.4 New Rules of Measurement (NRM) for Cost Planning

‘New Rules of Measurement (NRM)’ have been prepared by the Quantity Surveying and Construction Professional Group and published by the Royal Institute of Chartered Surveyors (RICS). NRM provides a standard set of measurement rules for estimating, cost planning, procuring and whole-life costing of construction projects. Ostrowski, (2013) stated that NR Mclearly and exactly sets down the procedure for producing an ‘Order of Cost Estimate’ or ‘Cost Plan’. He has also said that some previous cost plans had created frustration among the clients.NRM provides for a greater understanding by graduates/trainees as to how estimating and cost planning should be carried out by giving them a clear set of rules for doing this work. This is exactly why the industry needs to make quantity surveyors independent cost advisors given the increasing competition they face from other professionals. In addition, NRM exemplifies the best practices (Benge, 2014) by providing the basis for more accurate estimating through the provision of more useful cost advice that will help to establish more effective cost control systems and procedures to provide for greater employer and project team confidence. The rules are not restrictive, but provide a simple yet powerful toolkit for managing costs. They provide a uniform cost estimate and cost plan structure (Benge 2014). Although NRM is meant to provide a platform to do cost planning in UK, it was as there is no such standard document currently available in Sri Lanka.

The next section describes the methodology adopted in this research.

3.0. RESEARCH METHODOLOGY

A literature synthesis and expert interviews were carried out as the first step towards achieving the research aim that focused on cost planning practices followed by the construction industry in Sri Lanka. Since cost planning practices during the pre-construction stage have not been covered adequately in the local literature, the examination of the current cost planning practices and procedures was done through expert interviews. Qualitative approach was used in this research to propose a suitable cost plan since it requires investigating the cost planning practices applied in the construction industry. Semi-structured interview technique was used to collect data as it involves obtaining opinions and ideas from a sample rather than from experiments.

Thirteen (13) semi-structured interviews were conducted among expert Chartered Quantity Surveyors each of whom had more than ten years of experience and expertise in the construction field. The profile of interviewees is shown in Table 1.

Table 1: Profile of Interviewees

Respondent Code	Designation	Number of Years of Experience
EIRN1	Director/Project Manager	25
EIRN2	Director/Project Manager	25
EIRN3	Director	23
EIRN4	Director/ Project Manager	24
EIRN5	Director/ Senior Quantity Surveyor	15
EIRN6	Construction Administrator / Senior Quantity Surveyor	13
EIRN7	Director/ Senior Quantity Surveyor	11
EIRN8	Senior Quantity Surveyor	14
EIRN9	Senior Quantity Surveyor	17
EIRN10	Senior Quantity Surveyor/ Project Manager	15
EIRN11	Senior Quantity Surveyor	12
EIRN12	Senior Quantity Surveyor	14
EIRN13	Director/ Project Manager	16

The data collected from the semi-structured interviews were analyzed qualitatively by using N Vivo software. The data analysis and key research findings are described in Section 4.0.

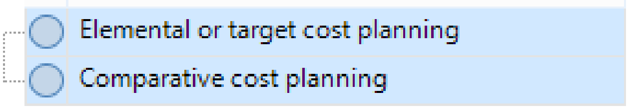
4.0.RESEARCH FINDINGS AND DISCUSSION

The key findings of the research are presented under the five (05) major headings given below.

- Cost planning methods/approaches currently used in the construction industry in Sri Lanka
- Cost estimation methods used in the construction industry in Sri Lanka
- Essential information obtained from each stakeholder for developing a good cost estimation
- Remedial actions that can overcome price fluctuations/changes in the general practice
- Necessity for a better cost planning approach in the construction Industry in Sri Lanka

4.1 Cost Planning Methods/Approaches Currently used in the Construction Industry in Sri Lanka

The two common cost planning methods, namely the elemental cost planning and comparative cost planning methods which were identified from the literature are used in the construction industry in Sri Lanka (refer Figure 1).



○ Elemental or target cost planning
○ Comparative cost planning

Figure 1: Types of cost planning methods

The data gathered from the expert interviews indicated that the method that is applied in the construction industry in Sri Lanka is a combination of the elemental cost planning method and the comparative cost planning method. As indicated by most of the respondents, the construction industry in Sri Lanka has adopted both elemental cost planning and comparative cost planning although their application and the conditions under which they are used can vary from firm to firm.

The analysis of the expert views also showed that the local construction industry has mostly adopted either elemental cost planning or comparative cost planning but that however there have been instances where the consultant has had to choose a combination of both approaches especially in complex projects involving vast amounts of money. Although the method of cost planning to be used is determined by the consultants based on their experience, the decision has to come from the client since the requirements could be different from one project to another. Furthermore, due to the unavailability of data during the initial stage or the briefing stage of a project, the consultant has to use some degree of estimation with appropriate assumptions to determine the final project cost before he prepares the detailed cost plan. Thus, having all required information will be important since good and accurate cost planning may depend on the details of the project available. Since the details available will be different from one stage to the other in construction, the preparation of a good cost plan will be different for each stage in the RIBA plan of work.

4.2 Cost Estimation Methods used in the Construction Industry in Sri Lanka

Cost estimation is one of the processes which are essential for preparing a detailed cost plan. It is the process of predicting the project cost based on certain sensible assumptions, before designing the project. There are two main classifications that were identified from the literature review and they are given in Figure 2.

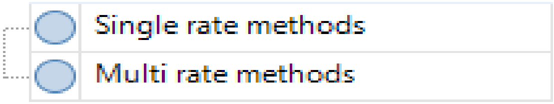


Figure 2: Types of cost estimation methods

Table 2 lists out the information gathered from the expert interviews. The data collected through expert interviews verified that four single rate methods, namely functional unit method, cube method, superficial area method and story enclosure method are applied in practice with the superficial area method being used by all of the experts. The functional unit method is also found to be used by a majority of experts.

Table 2: Evaluation of Single Rate Methods

Single Rates Methods	**EIRN1**	**EIRN2**	**EIRN3**	**EIRN4**	**EIRN5**	**EIRN6**	**EIRN7**	**EIRN8**	**EIRN9**	**EIRN10**	**EIRN11**	**EIRN12**	**EIRN13**
Functional Unit Method	×	×	×	×	×	×	-	×	×	×	-		×
Cube Method	×	×	×	×	×	-	×	×	×	×	×	-	-
Superficial Area Method	×	×	×	×	×	×	×	×	×	×	×	×	×
Story Enclosure Method	×	×	×	-	×	×	-	-	×	×	×	-	×

However, some consultants have used the cube method and the story enclosure method wherever they were applicable. Once the scope has been defined and the relevant information is obtained, the cost estimator starts working on the drawings by using a multi rate method.

Table 3: Evaluation of Multi Rate Methods

Single Rates Methods	**EIRN1**	**EIRN2**	**EIRN3**	**EIRN4**	**EIRN5**	**EIRN6**	**EIRN7**	**EIRN8**	**EIRN9**	**EIRN10**	**EIRN11**	**EIRN12**	**EIRN13**
Elemental Method	×	×	×	×	×	×	×	×	×	×	×	×	×
Approximate Quantity Method	×	×	×	×	×	×	×	×	×	×	×	×	×

In Sri Lanka, both the elemental multi rate method and the approximate quantity method are being used (refer Table 3). All experts indicated that they apply both methods in their cost estimations. The approximate quantity method is extensively applied in projects involving large amounts of money in which both the consultant and the client have to get involved.

4.3 Essential Information Obtained from Stakeholders for Developing an Accurate Cost Estimation

In developing correct cost estimations, the depth of information that can be obtained from the consultant will be significant. Since the accuracy of project details is important for cost estimation, the communications taking place between the consultants and the client will help the estimator to obtain proper information on the project from each stakeholder. It may also have a huge impact on the estimation. Table 4 presents some essential information that needs to be considered in cost estimation as revealed at the expert interviews.

Table 4: Information Required for Accurate Cost Estimation

Client	Architect	Civil Consultant	MEP Consultant
Project Details	Specifications	Foundation Details	Capacity of the Machines
Instructions	Finishes Schedule	Piling Design	System Specifications
Rentable Area	Floor Areas	Structural Specifications	Maintenance Details
Gross Floor Area	Plans		Air Cooling System
Net Area	Elevations		Water Cooling System
Preliminaries	Sections		Green Building Concept
Quality Level	Dimensions		
Function of the Building	No. of Floors		
	Quality Level		

If the consultants could collect all required information about the project including the information mentioned in Table 4, proper cost estimation would be possible. Most of the information is obtained during the preliminary stage of the project from the client and the architect also plays a key role during that stage.

4.4 Remedial Actions that can overcome Price Fluctuations/Changes in the General Practice

Price fluctuation or price escalation has to be considered when preparing the cost estimate since it is the factor that has the most influence on the cost estimate. In general practice, there is a specific allocation provided as a contingency sum to overcome this issue. The information presented in Table 5 was identified through the expert interviews as the information necessary for computing the contingency sum.

Table 5: Method to Overcome Price Fluctuations

Method to Make Allowances for Fluctuations	**EIRN1**	**EIRN2**	**EIRN3**	**EIRN4**	**EIRN5**	**EIRN6**	**EIRN7**	**EIRN8**	**EIRN9**	**EIRN10**	**EIRN11**	**EIRN12**	**EIRN13**
Central bank annual reports	×	×	×	×	×	×	×	×	×	×	×	×	×
Contingency sum	×	×	×	-	-	×	×	-	×	×	×	-	×
Current inflation in market	×	×	×	×	×	×	×	×	×	×	×	×	×
Get knowledge from reading newspapers	×	×	×	-	-	×	-	×	-	-	-	-	-
ICTAD publications	×	×	×	×	×	×	×	×	×	×	×	×	×
Own experience	-	-	-	-	×	-	-	×	×	-	×	-	-
Trends in past	×	×	×	-	×	-	×	×	-	-	-	-	-

The information given in Table 5 can be used to prepare cost estimates in the construction industry in Sri Lanka to overcome price fluctuations. It is clear that most of the experts cater to price fluctuations using ICTAD (CIDA) publications, the current inflation rate in the market and the Central Bank Annual Reports. Past trends, own experience, knowledge obtained from newspapers are the other general information used in the industry to compute the contingency sum.

4.5 Necessity for a Better Cost Planning Approach in the Construction Industry in Sri Lanka

According to the analysis of the different views of the experts, the construction industry in Sri Lanka does not still have proper documentation such as Bills of Quantities (BOQs), Frameworks for Cost Plans etc., for construction related works. Each consultancy firm uses its own formats for their work. Thus, it is essential to identify the suitability of the current system to provide an acceptable cost plan and to propose a suitable framework for the cost plan. As identified in the analysis, in Sri Lanka, the elements in the BOQ and the cost plan are different. Generally, the cost plan is based on elements like sub-structure, frame and roof but the BOQ has so many trades within each element and those trades are not covered in the cost plan under the respective elements, as the local construction industry does not have standard formats for the required documents. This is despite the fact that the construction industry in Sri Lanka is a major contributor to the growth of the country's economy. The cost overrun is a vital reason for the termination of a project. Thus, in order to avoid such unnecessary terminations, the construction industry in Sri Lanka needs to improve its cost planning practices. Hence, the drawbacks of the current system were identified to propose the probable solutions described later on.

Drawbacks of the Current System

Based on the analysis of the data gathered from the expert interviews, the drawbacks of the current system were identified. Table 6 illustrates these drawbacks.

Table 6: Drawbacks of the Current System

Drawbacks of the Current System	**EIRN1**	**EIRN2**	**EIRN3**	**EIRN4**	**EIRN5**	**EIRN6**	**EIRN7**	**EIRN8**	**EIRN9**	**EIRN10**	**EIRN11**	**EIRN12**	**EIRN13**
Poor awareness about the client's scope	-	-	-	-	-	-	×	-	-	-	×	×	-
Poor awareness about cost planning on the part of the client	-	-	×	-	-	-	-	-	-	-	×	×	-

Inaccuracy or unavailability of data	×	×	×	×	-	-	×	×	×	×	-	-	×
Designers having no idea about the system	-	×	×	-	-	-	-	-	-	-	-	-	-
Absence of a standard system	×	×	×	-	×	×	-	-	-	×	-	-	×
Lack of experience	-	-	-	-	-	×	×	-	×	-	-	×	-
Absence of a proper cost analysis system	×	×	×	-	-	×	-	-	-	-	-	-	-

The most common drawback is the inaccuracies found in the data since the quality of the cost plan will be dependent on the accuracy of the data. The next most common drawback is the absence of a standard system. In Sri Lanka, there is still no proper database available. As experts verified, each consultancy firm has its own database and follows its own systems/formats. This database has to be in a safe place in the absence of a central database provided by the government. In other countries, the same system is followed by all firms using a central database in which all required data is available. Even though the education system in Sri Lanka is on the lines of the education system in Britain, the industry in Sri Lanka is not following the industry in that country. Therefore, a person who joins the industry just after completing his/her studies will find it difficult to do a cost plan as the system and the format followed by the industry are different from what he/she has learned during his/her studies. Moreover, during the pre-construction stage, the client will need only a simple response to make financial arrangements. However during the initial stage where there is no exactly defined scope, the client can go on changing the scope up to the time of completing the project. Thus, there will be a variation between the amount in the cost plan and the total contract sum.

Solutions that will overcome the Drawbacks

Some recommendations can be proposed based on the outcome of the expert interviews to overcome the drawbacks identified. Table 7 shows the strategies that can overcome the drawbacks of the current practices in the construction industry.

Table 7: Proposed Solutions

Solutions Proposed	**EIRN1**	**EIRN2**	**EIRN3**	**EIRN4**	**EIRN5**	**EIRN6**	**EIRN7**	**EIRN8**	**EIRN9**	**EIRN10**	**EIRN11**	**EIRN12**	**EIRN13**
Advising clients to adhere to the system				×				×			×		
Developing a central database management system	×	×	×						×	×	×	×	
Developing a mechanism to exchange data from firm to firm	×	×	×	×		×			×	×			×
Following standard methods that are already being practiced					×			×	×				×
Developing a standard cost plan and cost analysis				×		×			×	×			×
Obtaining practical experience in cost planning		×	×		×	×	×			×			
Publishing past records at least on websites for use in future projects	×	×	×			×	×	×				×	

Use of special computer software packages	×	×	×	×	×			×		×		×	×

As illustrated in Table 7, the use of computer aided packages specifically designed for cost planning is the best solution to overcome the drawbacks. Packages like Building Information Modeling (BIM), Cost –X, Revit etc., are being used frequently for cost estimation in most of the developed countries. Similarly, local government authorities and institutions in Sri Lanka can develop and implement necessary procedures to motivate the construction industry to use these computer packages. Furthermore, the exchange of data from one firm to another will highly assist in overcoming the drawbacks. Sharing of information will create a large pool of data from which all required information can be obtained with high accuracy. However, the sharing of cost data of an organization with others will have an impact on the privacy of that firm which can affect its survival in the long run. The Government of Sri Lanka can provide published cost data within a particular time interval by using a centralized database. This information can be made available to all stakeholders by providing them with easy access to the database. Since it is published by the local government bodies, the reliability of the cost data would be high and that data could be used as references. It is required especially for infrastructure projects like roads, damps, bridges, railway projects etc., for which cost data would be difficult to obtain and maintain. However, the data published will be only typical data as they will indicate the market values only approximately.

5.0 PROCEDURAL FRAMEWORK SUITABLE FOR COST PLANNING PRACTICES IN SRI LANKA DURING THE PRE-CONSTRUCTION STAGE

Even with the local construction industry adopting different frameworks for cost planning, each consultancy firm maintains several exclusions in their cost plans. Those typical exclusions were identified during data collection and compared with the NRM cost plan framework. A framework based on them has been suggested to suit the practices in Sri Lanka.

Facilitating Works

Facilitating works included in the first stage of the NRM framework were compared with those stated in the formats used in Sri Lanka. Since all the experts indicated that the cost plans used in their respective organizations include facilitating works, this stage can be included in the standard format proposed for Sri Lanka. It briefly gives the preparation works that shall be carried out prior to construction. Rightfully, it has been accepted by all the experts as facilitating an accurate cost plan.

Sub-structure

Sub-structure is an important element in a construction. All practitioners include it in their cost planning format, and thus this element needs to be included in the format developed for Sri Lanka as well. It has also to be noted that around 10% of the total cost of a project shall be allocated to sub-structure work as per the norms. Therefore, the sub-structure cost plan will have a heavy positive impact on the accuracy of the cost estimate. It also can be included in the standard format for Sri Lanka.

Super-structure

Super-structure is another important element in a building. The architect provides the door and window schedule during the early stage of a project, enabling the experts to include not only the frame, upper floors, roofs and staircases but also the external walls, external doors and windows, partition walls and internal doors. Similarly, a major portion of the budget is allocated for the super-structure of a building and therefore the inclusion of super-structure items in the cost plan will increase the accuracy of the cost estimation of a project. The interviewees have endorsed this by marking all super- structure elements. Therefore, all super-structure elements can be taken into account when preparing the standard format for practice by the local industry.

Internal Finishes

Internal finishes is a costly element that has a heavy impact on the project cost. Some respondents have given only a few suggestions regarding the cost of the internal finishes. Therefore, a provisional sum can be allocated in the cost plan for internal finishes and it can be modified at the client's discretion. However, it shall be noted that the cost of internal finishes needs to be included in the plan as it may have a significant impact on the cost of the project.

Fittings, Furniture and Equipment

Since the cost of fittings, furniture and equipment is outside the initial budget, the cost for same may not be included in the cost plan. It is mostly decided by the client at the end, probably after the construction is completed. Therefore, it is not necessary to provide for them in the cost plan at the beginning. Furthermore, the consultant cannot predict whether the client will have them as per the design or whether he will modify them during the construction period and this will affect the accuracy of the cost plan.

Services

Services will consume nearly 30% of the total construction cost. However in Sri Lanka, only a few elements are covered by the consultant unlike in the NRM framework and those were identified during data collection. Electrical, water and disposal systems were especially covered by local practitioners. Therefore, these items can be included in the standard format for Sri Lanka. On the other hand, the lack of cost data related to building services will be a challenge to developing an accurate cost plan. In most of the projects, cost data of services are not recorded and maintained in a standard way, as they can vary with time due to changes made in the design to suit client's requirements and building formation. However, if the standard format of the government includes services, it will be useful to maintain records on the services.

Pre-Fabricated Buildings and Building Units

Although respondents have wanted pre-fabricated buildings and building units to be included in the standard format, these are still not familiar to the local construction industry. As the local construction industry begins to build pre-cast and pre-fabricated units to reduce time and cost while at the same time increasing the quality of construction, they will become more common in future. Therefore, all interviewees have rightfully ticked and emphasized that they shall be included in the standard format for Sri Lanka. Furthermore, these types of construction will facilitate the use of cost plans efficiently with high accuracy.

Work on Existing Buildings

Work on existing buildings includes any demolitions or alterations to an existing building and damp proof coat, fungus and beetle eradication, façade retention, cleaning of the surface and renovation works. All these will be carried out only if they are requested by the client and will not be generally a common element in building construction. As a result, these items may be included if applicable. However in the local construction industry especially at domestic level, there is more renovation work of this type than new constructions. Therefore, these also need to be included in the standard format as indicated by the respondents.

External Works

External works is another element which the local construction industry can adopt from the NRM framework. These external works include landscaping, road construction, external services etc., which are frequently required especially in infrastructure projects. As Sri Lanka is a developing country, these can be useful when planning the national budget using cost plans. All of the experts also mentioned that they can be directly applied to Sri Lanka and that therefore they need to be included in the standard format.

Main Contractor’s Preliminaries

Main contractor’s preliminaries include all temporary works that are required in permanent construction works. It includes all the items that a contractor will require to proceed with especially during the initial stage of a project and also during its construction period. The items listed under this will vary based on the type and the nature of the project. Therefore, it will not be possible to prepare a common list under this category. All of the respondents have also indicated that it will not be proper to include them in the standard cost plan format of Sri Lanka.

Main Contractor’s Overheads and Profits

Main contractor’s overheads and profits are also like the preliminary items discussed in the previous section. The contractor’s overheads basically include all others that are not listed under preliminaries. Their percentages will differ based on the contractor’s position in the industry; type, nature and value of the project; local regulations and standards etc. As a result, it is not possible to define these items if they are to be included in the standard cost plan format. The respondents have also mentioned that it may not be possible to consider them in the format. However, preliminaries and overhead and profit components will add a significant value to the final cost plan.

Project Design Team Fee

Just as the contractor’s fee, the project design team fee also needs to be considered in preparing the cost plan although the design fee will be less than the construction fee. A sum shall be allocated for the design fee in the cost plan when preparing it for a particular project. However, it will not be possible to include it as atypical standard, as it will vary depending on the nature of the project. Rightfully, respondents have not marked it as an item required in the standard format.

Other Development and Project Costs

Similar to the main contractor’s preliminaries, main contractor’s overheads and profits; project and design team fees and other development and project costs also have to be excluded, as stated by all experts, in the format to be developed for Sri Lanka. They are unique costs that will not be applicable to all projects, as they can vary depending on the type and position of the organization.

Setting and Managing Risk Allowances

These items should be considered where necessary and if applicable, they can be included in the format developed for Sri Lanka. Alternatively, a considerable component of the cost shall be allocated for it as most of the projects are subjected to risks in various forms. Then only it will be possible to develop a reliable cost plan and the cost predicted accordingly.

Effects of Inflation

The possible effect of inflation should be included in any estimate, since all projects are subjected to inflation either during the tendering stage or the construction stage or in both. Therefore, a significant amount needs to be allocated in the cost plan for price inflation. However, it will depend on the Local Government Act and Ordinance which can get amended as and when the need arises. It will therefore be unpredictable. As a result, it cannot be included in the standard cost plan format and correctly all respondents have agreed to leave it out from the standard format.

Taxes and Incentives

Taxes and incentives were also completely left out by the industry experts. While preparing a cost plan, taxes will not be considered as they will undergo frequent variations and will be shown separately after compiling all other costs. Consequently, they can be taken off from the framework.

Framework Suitable for the Construction Industry in Sri Lanka

As indicated in Table 8, the elements marked 100% by the experts can certainly be used in the preparation of the standard format. The elements that have been marked 69% and 53% can also be included in the cost plan, as they are expected to be at a suitable level. The items marked 23% can be included only if necessary. This will be decided based on the requirements of the particular project and the availability of cost data for the estimate. Accordingly, the framework for the cost plan of the standard format may be developed as shown in Table 8.

Table 8: Suitability of NRM Framework for the Construction Industry in Sri Lanka

NRM Framework	Suitability Percentage for the Construction Industry in Sri Lanka
Facilitating Works	100%
Sub-structure	100%
Super-structure	100%
Internal Finishes	69%
Fittings, Furniture and Equipment	23%
Services	50%
Services Equipment	100%
Disposal Installations	100%
Water Installation	100%
Electrical Installation	100%
Builder's Work in Connection with Services	100%
Pre-fabricated Building and Building Units	100%
Work of the Existing Building	100%
External Works	100%
Main Contractor’s Preliminaries	0%
Project and Design Team Fees	0%
Other Development and Project Costs	0%
Settings and Managing Risk Allowances	69%
Estimating the Possible Effects of Inflation	0%
Taxes and Incentives	0%

Some stages in the NRM framework relating to main contractor's preliminaries, project and design team fees, other development and project costs, estimating the possible effects of inflation and taxes and incentives have been excluded in the cost planning framework developed for Sri Lanka.

6.0 CONCLUSIONS

In the local construction practice, there are two major methods for cost planning, namely elemental cost planning method and the comparative cost planning methods which were also confirmed from the literature review and from experts. In addition to those two methods, a hybrid method formed by combining the elemental and comparative methods which is being used in the local construction industry was also identified from the expert interviews. In most of the construction projects in Sri Lanka, the RIBA plan of work is being adopted as the standard framework the construction of projects designed and defined by the relevant local authorities. CIDA is now maintaining some cost data irrespective of the location of the project and other factors, for developing a common platform for estimation. Alternatively in Sri Lanka, most of the cost data are maintained within each firm for their own use and are known as" In-House data". The local construction industry does not follow a standard format for documentation in the construction projects. However, there would not be any similarities between the BOQ and the Cost Plan at the end of estimation. Accordingly, the drawbacks of the current system that have been identified in the study need to be addressed and a standard format appropriate for local practices has to be developed. A standard framework was developed in this study by incorporating the RIBA plan of work into the Sri Lankan standards.

Based on the review of existing industry practices, the construction industry should first follow standard documentation in cost planning. Nevertheless, the cost planning practices in Sri Lanka have to be appropriately monitored. The NRM framework can be used as a guideline in preparing the correct cost plan albeit with several exclusions since the nature and the practice of the local construction industry are different from those of other countries. The final outcome of this research can be used for the framework that best suits Sri Lanka. However, there was some special consideration on project specification. Along with all necessary information, the framework developed can be used in the building construction projects in Sri Lanka to overcome cost overruns through a proper cost planning procedure.

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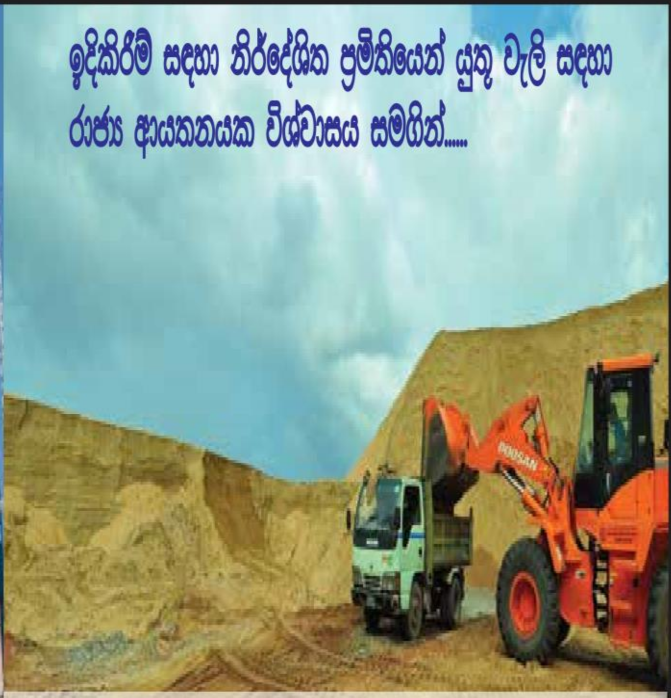

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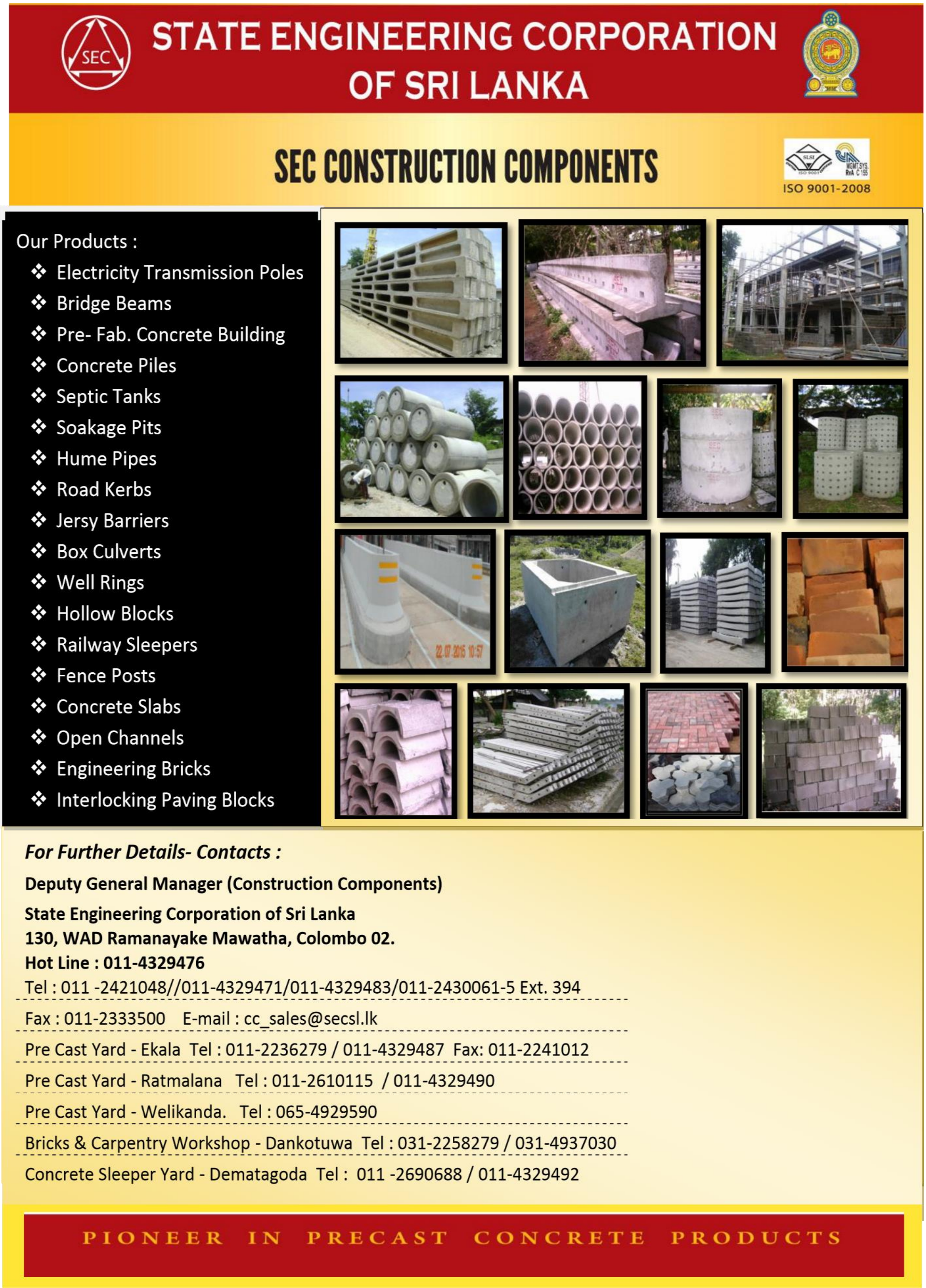

AWARD WINNERS 2016 & 2017

Construction Excellence Awards & Construction Merit Awards for

Building Projects

Year	Type of Award	Project and Recipient
2016	Excellence	Design and Construction of Secretariat for Personal Identification for Ministry of Defence & Urban Development at Battaramulla. by International Construction Consortium (Pvt) Ltd.
	Excellence	On three 20 Condominium Project at Union Place. by Sanken Construction (Pvt) Ltd.
	Excellence	Housing for Relocation of Underserved Settlements in the City of Colombo. by Access Engineering PLC
	Excellence	Design and Construction of Iceland Business Centre at Colombo 03 by International Construction Consortium (Pvt) Ltd.
	Excellence	Bottling Plant Complex at Munidasa Kumarathunga Mawatha, Seeduwa by R N Constructions (Pvt) Ltd.
	Excellence	Commercial Building – Dialog Axiata PLC at 475 A, Union Place, Colombo 2. by Tudawe Brothers (Pvt) Ltd.
	Excellence	Supply and Installation of Aluminium Doors, Windows, Composite Panels, Entrance Foyer and Atrium Roof for Secretariat for Personnel Identification, Ministry of Defence and Urban Development at Battaramulla by AJAX Engineers (Pvt) Ltd.
	Merit	Apartment Complex – The Fairway Sky Garden at 39, Perera Mawatha, Rajagiriya. by Maga Engineering (Pvt) Ltd.
	Merit	Highways Secretariat Building at Battaramulla by Nawaloka Construction Company (Pvt) Ltd.
	Merit	Six Storied Co-operative Hospital Building at Galle. by Sripalie Contractors (Pvt) Ltd.
	Merit	Branch Office for People’s Bank at Hatharaliyadda, Kandy. by Kemyo (Pvt) Ltd.
	Excellence	Building Complex for National School of Business Management at Homagama by Maga Engineering (Pvt) Ltd.

Year	Type of Award	Project and Recipient

2017	Excellence	154 roomed five star Hotel for Pease Haven Resort (Pvt) Ltd. at Tangalle by International Construction Consortium (Pvt) Ltd.
	Excellence	Office Complex for RIL Property (Pvt) Ltd. at Colombo 02 by Nawaloka Construction Company (Pvt) Ltd.
	Excellence	Extension to the Treasury Building at Colombo 01 by Maga Engineering (Pvt) Ltd.
	Excellence	Razavi Medical Complex at the Cancer Hospital Maharagama by Nawaloka Construction Company (Pvt) Ltd.
	Excellence	Ani Villas Resort at Dikwella by Salasi Lanka (Pvt) Ltd.
	Excellence	Rainbow Business Centre at Colombo 04 by International Construction Consortium (Pvt) Ltd.
	Excellence	Additions, Alterations, Refurbishments to British Council at Colombo 3 by L H Piyasena & Co. (Pvt) Ltd.
	Merit	Tutory Building for International College of Business & Technology (ICBT) at Colombo 04 by N & A Engineering Services (Pvt) Ltd.
	Merit	Eight Storied Office Building for Wickramaratnes (Pvt) Ltd. at Colombo 03 by Tudawe Brothers (Pvt) Ltd.

Electro Mechanical Construction Awards

Year	**Type of Award**	**Project and Recipient**
2017	Merit	Electrical Installation (Low Voltage) - Rainbow Business Centre at Colombo 04. by Kent Engineering (Pvt) Ltd.
	Merit	Supply and Installation, Testing & Commissioning of Air Conditioning and Ventilation System - Rainbow Business Centre at Colombo 04. by Kent Engineering (Pvt) Ltd.

Green Construction Award

Year	**Type of Award**	**Project and Recipient**
2017	Merit	Design & Construction of National Environmental Secretariat for Ministry of Mahaweli Development and Environment at Battaramulla by Central Engineering Consultancy Bureau

Construction Performance Awards for Civil Engineering Projects (assessed after completion)

2016	**Category I - value exceeding Rs: 1000 million** Improvements to Bodagama – Hambegamuwa – Kaltota Road (B528) (from 0+000 km to 48+200 km) Contract No. RDA/DW/UVA/LBFP/2011/392 by Maga Engineering (Pvt) Ltd. Rehabilitation & Improvements of Bangadeniya – Andigama – Anamaduwa (B45) Road (from 0+000 to 38+000) Contract No. RDA/DW/NWP/GOSL/2011/347A by Access Engineering PLC Rehabilitation & Improvements of Kurunegala – Narammala – Madampe Road (from 40+870 to 64+770 km) Contract No. RDA/DW/NWP/LBFP/2011/753B by NEM Construction (Pvt) Ltd. Rehabilitation of national highways with concrete surfacing through domestic contractors Waskaduwa – Bandaragama Road (B-458) (0+000 to 12+070 km) & Kesbewa – Kidelpitiya – Bandaragama Road (B-216)(0+000 to 11+780 km) Contract No. RDA/DW/WP/GOSL/2011/453 by K D Ebert & Sons Holdings (Pvt) Ltd. Rehabilitation of Pannala – Kuliyapitiya Road (B356) (5.0 to 16.28km) & Kuliyapitiya – Hettipola Road (B243) (0.00 to 15.69km) Contract No. RDA/DW/NWP/GOSL/2011/425 by NEM Construction (Pvt) Ltd. Widening and Re-construction of Matara – Hakmana Road Project (from 0+000 km to 24+140 km) Contract No. RDA/DW/SP/GOSL/2012/10 by Maga Engineering (Pvt) Ltd. Rehabilitation and Improvements to B-157(west) Road Section from Aluthgama to Southern Expressway (42+600 to 53+670 km) Contract No. RDA/NHSP/ICB/ADB/CP-3 by K D A Weerasinghe & Co., (Pvt) Ltd. Rehabilitation & Improvements to A017 Galle - Deniyaya – Madampe Road Section from Rakwana to Madampe (130+000km – 143+930km) Contract No. RDA/MFAP/ICB/OPID-1/01 by Maga Engineering (Pvt) Ltd. Rehabilitation & Improvements to A017 Galle - Deniyaya – Madampe Road Section from Rakwana to Madampe (130+000km – 143+930km) Contract No. RDA/MFAP/ICB/OPID-1/01 by Maga Engineering (Pvt) Ltd. Rehabilitation & Improvements of Kurunegala – Narammala – Madampe Road

	(from 22+260 to 40+870 km) Contract No. RDA/DW/NWP/LBFP/2011/753A by Consulting Engineers & Contractors (Pvt) Ltd.
Construction Performance Awards for Civil Engineering Projects (assessed after completion)	
2016	Rehabilitation & Improvements of Galagedara – Rambukkana Road (from 0.0 to 18.50 km) Contract No. RDA/RNIP/PRP2/PACKAGE-C/ C7(iii) by Access Engineering PLC Rehabilitation & Improvements to A001 Colombo – Kandy Road Section from Peliyagoda to Kiribathgoda (5+860 km – 13+100 km) Contract No. RDA/MEAP/ICB/SFD-2/07 by Maga Engineering (Pvt) Ltd. Metro Colombo Urban Development Project. Rehabilitation of Galle Road and R A De Mel Mawatha, from Liberty Roundabout to Dharmapala Road Junction. Contract Package C, Contract No MCUDP/CMC/W/12(C) by International Construction Consortium (Pvt) Ltd. Metro Colombo Urban Development Project. Rehabilitation of Galle Road from Bambalapitiya Junction to South City Limit - Contract Package B, Contract No MCUDP/CMC/W/12(B) by International Construction Consortium (Pvt) Ltd. **Category II - valued between Rs: 500 million & 1000 million** Rehabilitation / Improvements of A029 Vavunia – Horowpatana Road (from 24+000 km to 34+950 km) Contract No. RDA/NRCP(AF)/ICB/ADB/CP-11 by International Construction Consortium (Pvt) Ltd. Metro Colombo Urban Development Project. Rehabilitation of Galle Road and R A De Mel Mawatha, from Galadari Roundabout to Kollupitiya Junction. Contract Package A, Contract No MCUDP/CMC/W/12(A) by International Construction Consortium (Pvt) Ltd. Design, Supply and Construction of Polduwa Bridge Contract No. RDA/UKSBP2/PLDW/006 by Access Engineering PLC Construction of Kandana Water Treatment Plant Extension Contract No. WSDP/KGWSP-P1 S2/ICB-01 by Access Engineering PLC **Category III - valued between Rs: 100 million & 500 million**

	Construction of Elevated Water Tower, Office Building, Quarters, Stores and Supply and Laying of Transmission Main and Distribution Mains of Echchalampattu Water Supply Scheme. Contract No. P&D/SE/ADB/CARE/EP/2011/01 by K D A Weerasinghe & Co., (Pvt) Ltd.

Construction Performance Awards for Civil Engineering Projects (assessed after completion)	
2016	ADB funded Nothern Roads Connectivity Project – Additional financing (Provincial Component) – ADB Loan No.2890(SF) 2891(Sri) Contract No. NRCP/NP/NCB/KL02 by Maga Engineering (Pvt) Ltd. ADB funded Nothern Roads Connectivity Project – Additional financing (Provincial Component) – ADB Loan No.2890(SF) 2891(Sri) Contract No. NRCP/NP/NCB/MU01 by Maga Engineering (Pvt) Ltd. Reconstruction of Bridge No 3/2 (Karadana Bridge) on A-019 Polgahawela – Kegalle Road Contract No. RDA/MFAP/ICB/OFID-1/03 by V V Karunaratne & Company Remedial Works of New Laxapana Power Tunnel Contract No. DSWRPP-AF/WORKS/DC/151 by State Development & Construction Corporation
2017	**Category I - value exceeding Rs: 1000 million** Rehabilitation and upgrading of Bibile – Pitakumbura – Namaloya – Inginiyagala Road (from 0+000 to 60+310 km) Contract No.W/UVA/GOSL/2011/731 by Tudawe Brothers(Pvt) Ltd. ADB funded Northern Roads Connectivity Project – Additional Fencing – Rehabilitation / Improvements of AB019 Jaffna – Pannai – Kayts Road (from 0+000 to 10+000 km) Contract No. RDA/NRCP(AF)/ICB/ADB/CP-18 by Maga Engineering (Pvt) Ltd. Rehabilitation and Improvements to Haputhale – Boralanda – Keppetipola Road (B353) (from 0+000 to 27+000 km) Contract No. RDA/DW/UVA/LBFP/2012/271 by Consulting Engineers & Contractors (Pvt) Ltd. Rehabilitation of National Highways with Concrete Surfacing through Domestic Contractors Anamaduwa – Uswewa – Galgamuwa Road (from 0+000 to 39+100 km) Contract No. RDA/DW/CP/GOSL/2011/347 by Edward & Christie (Pvt) Ltd.

	Rehabilitation and Improvements to Ambepussa – Kurunegala – Trincomalee Road fro Dambulla to Galewela (from 75+000 to 90+100 km) Contract No. RDA/DW/CP/LBFP/STAGE 2/2013/02 by International Construction Consortium (Pvt) Ltd. Rehabilitation & Upgrading of Thoppuwa – Dankotuwa – Naththandiya – Madampe Road (B419) (from 0+000 to 26+650 km) Contract No. RDA/DW/NWP/GOSL/2011/454(B) by CML - MTD Construction Ltd.

Construction Performance Awards for Civil Engineering Projects (assessed after completion)	
2017	Rehabilitation and Improvements to Polonnaruwa – Hingurakgoda Road (from 2+000 to 13+650 km) Contract No. RDA/DW/NCP/LBFP/2013/032(A) by NEM Construction (Pvt) Ltd. **Category II - valued between Rs: 500 million & 1000 million** Rehabilitation & Improvements to Mallawapitiya – Rambodagalla – Keppitigala Road (from 0+000 to 10+000 km) Contract No. RDA/DW/NWP/LBFP/STAGE-02/2013/45 by A M S K Constructions (Pvt) Ltd. Rehabilitation of Secondary Distribution System in Slave Island and Hultsdorf Area in Colombo – Kalu Ganga Water Supply Project (Phase I Stage II) Contract No. WSDP/CIVIL/JICA/KGWSP-P1 S2/2013/NCB-Package (A) by Squire Mech Engineering(Pvt) Ltd. **Category III - valued between Rs: 100 million & 500 million** Construction of Treatment Plant and Design, Fabricate, Supply & Installation of Steel Pipe Rack for Bottlig Plant Complex for Distilleries Company of Sri Lanka at Seeduwa by R H Steel Building Systems (Pvt) Ltd. Remedial Works of Nalanda Dam Contract No. DSWRPP-1/WORKS/ NCB/06 by CML - MTD Construction Ltd. Improvements to Hatton – Nuwaraeliya Road Project Construction of Kotagala Tunnel & Ancillary Works of Kotagala Railway Underpass Contract No. RDA/MFAP/EDCF/HNE/WKS/IV by E L S Constructions(Pvt) Ltd. Asphalt paving works for Colombo Port Expansion Project – East Container Terminal – Phase I Sub Contract No. CILP-SC-E-012 by Access Engineering PLC

	Construction of Canal Bank Protection Works of St. Sebastian South Canal Contract No. MCUDP/SLLRDC/W/03-A by Access Engineering PLC Widening of Bridge No. 2/1 on Narahenpita – Nawala – Nugegoda Road Contract No. RDA/MFAP/ICB/OFID-2/14 by CML - MTD Construction Ltd.

Awards for Innovative Techniques in Construction

2016	Construction of Trough Across Kon Oya Contract No. ID/HO/DORP/01,02,03/2010 by State Development & Construction Corporation

Awards for Environmental Friendly Innovative Construction Related Technology

2017	Expanded Polystyrene Light Weight Concrete Sandwich Panel by Ekala Prestressed Concrete Industries (Pvt) Ltd.

Awards for Construction Performance (Building & Civil Engineering)
(Awards to Overseas Projects by Domestic Construction Contractors)

2017	Construction of Channel and Aqueducts (from 1+100 to 2+047), Forebay & Spillway, Power House, Tailrace & related Civil Works of Muvumbe Small Hydro Power Project, Uganda by Sanken Overseas (Pvt) Ltd. Construction of Building & Associated Works - Mombasa Port Development Project, Kenya by Sanken Overseas (Pvt) Ltd. Design & Construction of 120 room Amari Havodda Resort, Maldives by Sanken Overseas (Pvt) Ltd.


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NATIONAL AWARDS FOR CONSTRUCTION EXCELLENCE & CONSTRUCTION MERIT – 2017

(FOR BUILDING PROJECTS)

NATIONAL AWARD FOR CONSTRUCTION EXCELLENCE – 2017

Category I - value exceeding **Rs: 750 million**

Building Complex for National School of Business Management at Homagama

Contractor : Maga Engineering (Pvt) Ltd.

NATIONAL AWARD FOR CONSTRUCTION EXCELLENCE – 2017

Category I - value exceeding **Rs: 750 million**

154 roomed five star Hotel for Peace Haven Resort (Pvt) Ltd. at Tangalle

NATIONAL AWARD FOR CONSTRUCTION EXCELLENCE – 2017

Category I - value exceeding **Rs: 750 million**

Office Complex for RIL Property (Pvt) Ltd. at Colombo 02

Contractor : Nawaloka Construction Company (Pvt) Ltd

NATIONAL AWARD FOR CONSTRUCTION EXCELLENCE – 2017

Category I - value exceeding **Rs: 750 million**

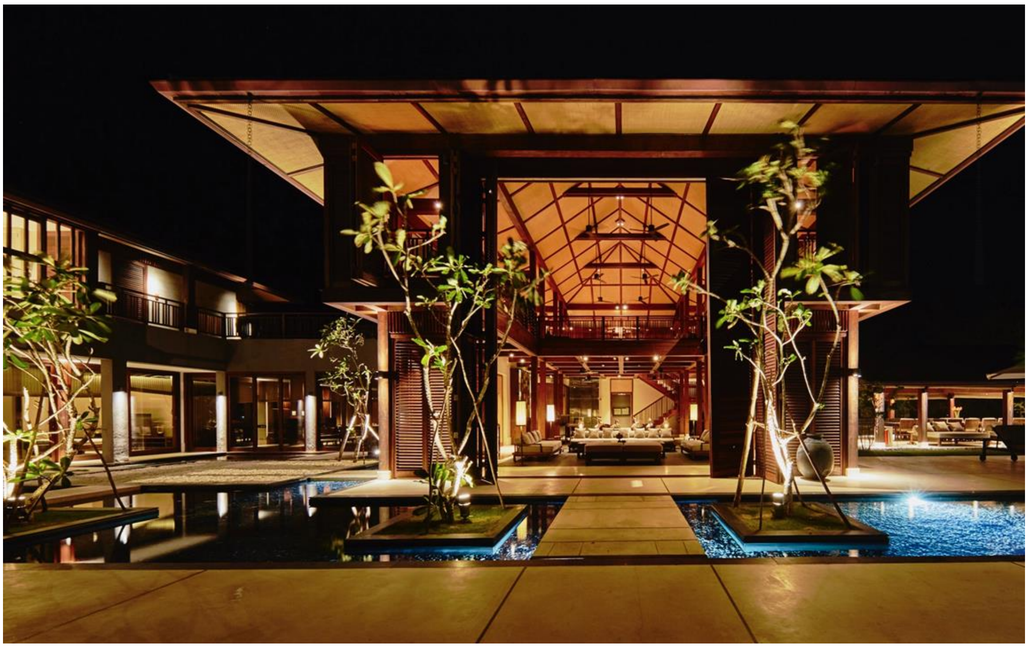
Extension to the Treasury Building at Colombo 01

NATIONAL AWARD FOR CONSTRUCTION EXCELLENCE – 2017

Category I - value exceeding **Rs: 750 million**

Razavi Medical Complex at the Cancer Hospital Maharagama

Contractor : Nawaloka Construction Company (Pvt) Ltd



NATIONAL AWARD FOR CONSTRUCTION EXCELLENCE – 2017

Category II - value in between **Rs: 450 million & 750 million**

Ani Villas Resort at Dikwella

NATIONAL AWARD FOR CONSTRUCTION EXCELLENCE – 2017

Category II - value in between **Rs: 450 million & 750 million**

Rainbow Business Centre at Colombo 04

Contractor : International Construction Consortium (Pvt) Ltd.

NATIONAL AWARD FOR CONSTRUCTION EXCELLENCE – 2017

Category III - value in between **Rs: 150 million & 450 million**

Additions, Alterations, Refurbishments to British Council at Colombo 3

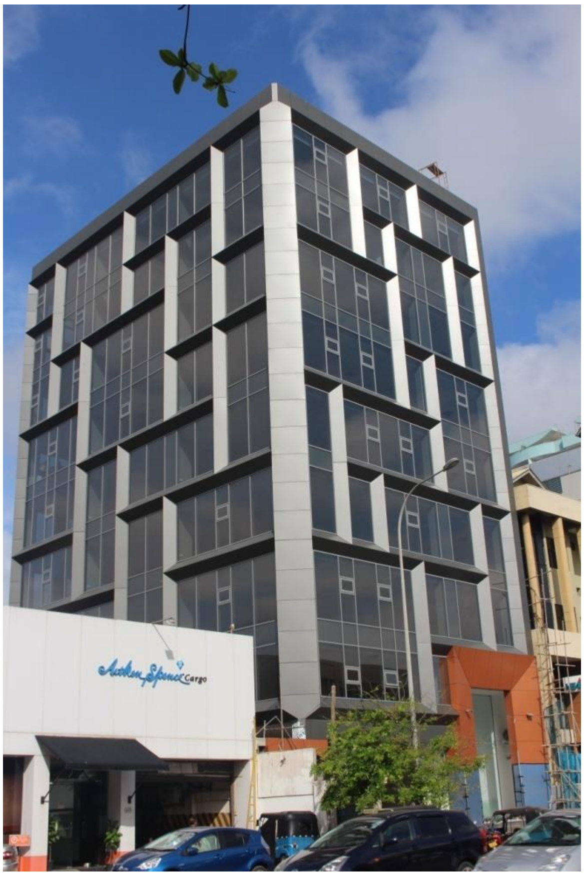
Contractor : J H Piyasena & Co. (Pvt) Ltd

NATIONAL AWARD FOR CONSTRUCTION MERIT– 2017

Category II - value in between **Rs: 450 million & 750 million**

Tutory Building for International College of Business & Technology (ICBT) at Colombo 04

Contractor : N & A Engineering Services (Pvt) Ltd

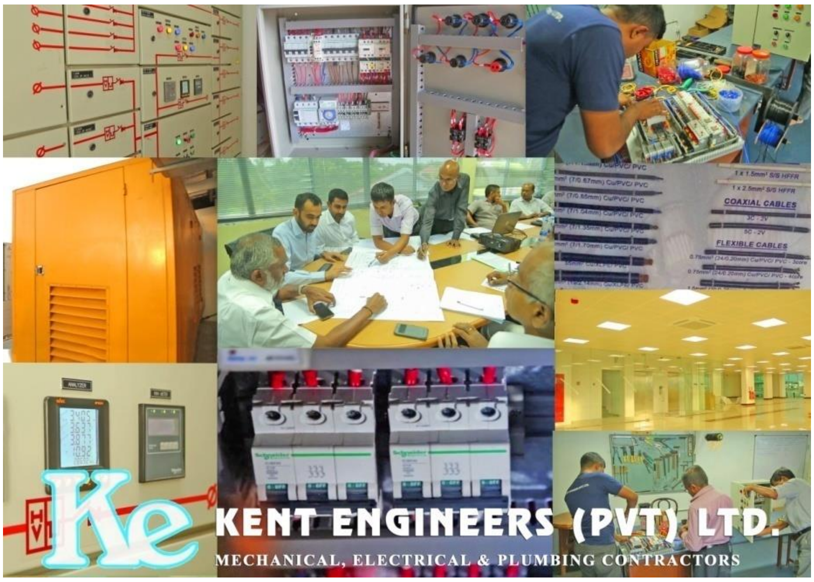


NATIONAL AWARD FOR CONSTRUCTION MERIT– 2017

Category III - value in between **Rs: 150 million & 450 million**

Eight Storied Office Building for Wickramaratnes (Pvt) Ltd. at Colombo 03

Contractor : Tudawe Brothers (Pvt) Ltd



MERIT AWARD - 2017

Category II - valued between **Rs: 25 million & 50 million**

Electrical Installation (Low Voltage) - Rainbow Business Centre at Colombo 04.

Contractor : Kent Engineering (Pvt) Ltd

MERIT AWARD - 2017

Category IV - valued between **Rs: 25 million & 50 million**

Supply and Installation, Testing & Commissioning of Air Conditioning and Ventilation System - Rainbow Business Centre at Colombo 04

Contractor : Kent Engineering (Pvt) Ltd

NATI

(FOR CIVIL ENGINEERING PROJECTS)
(Assessed after completion)

National Award for Construction Performance 2017

Category I - value exceeding Rs: 1000 million

Rehabilitation and upgrading of Bibile – Pitakumbura – Namaloya – Inginiyagala Road

(from 0+000 to 60+310 km)

Contract No.W/UVA/GOSL/2011/731

National Award for Construction Performance 2017

Category I - value exceeding Rs: 1000 million

ADB funded Northern Roads Connectivity Project Additional Fencing – Rehabilitation / Improvements of AB019 Jaffna – Pannai – Kayts Road

(from 0+000 to 10+000 km)

National Award for Construction Performance 2017

Category I - value exceeding Rs: 1000 million

Rehabilitation of National Highways with

Concrete Surfacing through Domestic Contractors Anamaduwa – Uswewa – Galgamuwa Road

(from 0+000 to 39+100 km)

National Award for Construction Performance 2017

Category I - value exceeding Rs: 1000 million

Rehabilitation and Improvements to Ambepussa – Kurunegala – Trincomalee Road from Dambulla to Galewela (from 75+000 to 90+100 km)

Contract No. RDA/DW/CP/LBFP/STAGE 2/2013/02

National Award for Construction Performance 2017

Category I - value exceeding Rs: 1000 million

Rehabilitation & Upgrading of Thoppuwa – Dankotuwa – Naththandiya – Madampe Road (B419)

(from 0+000 to 26+650 km)

Contract No. RDA/DW/NWP/GOSL/2011/454(B)

National Award for Construction Performance 2017

Category I - value exceeding Rs: 1000 million

Rehabilitation and Improvements to Polonnaruwa – Hingurakgoda Road (from 2+000 to 13+650 km)

Contract No. RDA/DW/NCP/LBFP/2013/032(A)

by NEM Construction (Pvt) Ltd.

National Award for Construction Performance 2017

Category II - valued between Rs: 500 million & 1000 million

Rehabilitation & Improvements to Mallawapitiya – Rambodagalla – Keppitigala Road

(from 0+000 to 10+000 km)

Contract No. RDA/DW/NWP/LBFP/STAGE-02/2013/45

National Award for Construction Performance 2017

Category II - valued between Rs: 500 million & 1000 million

Rehabilitation of Secondary Distribution System in Slave Island and Hultsdorf Area in Colombo –

Kalu Ganga Water Supply Project

(Phase I Stage II)

Contract No. WSDP/CIVIL/JICA/KGWSP-P1 S2/2013/NCB-

National Award for Construction Performance 2017

Category III - valued between Rs: 100 million & 500 million

Construction of Treatment Plant and Design, Fabricate, Supply & Installation of Steel Pipe Rack for Bottlig Plant Complex for Distilleries Company of

Sri Lanka at Seeduwa

National Award for Construction Performance 2017

Category III - valued between Rs: 100 million & 500 million

Remedial Works of Nalanda Dam

Contract No. DSWRPP-1/WORKS/ NCB/06

by CML - MTD Construction Ltd.

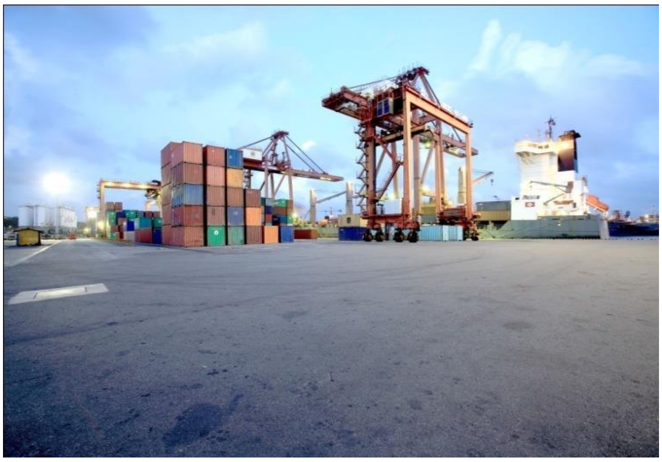
National Award for Construction Performance 2017

Category III - valued between Rs: 100 million & 500 million

Improvements to Hatton – Nuwaraeliya Road Project

Construction of Kotagala Tunnel & Ancillary Works of Kotagala Railway Underpass

Contract No. RDA/MFAP/EDCF/HNE/WKS/IV



National Award for Construction Performance 2017

Category III - valued between Rs: 100 million & 500 million

Asphalt paving works for Colombo Port Expansion Project – East Container Terminal – Phase I

Sub Contract No. CILP-SC-E-012

by Access Engineering PLC

National Award for Construction Performance 2017

Category III - valued between Rs: 100 million & 500 million

Construction of Canal Bank Protection Works of

St. Sebastian South Canal

Contract No. MCUDP/SLLRDC/W/03-A

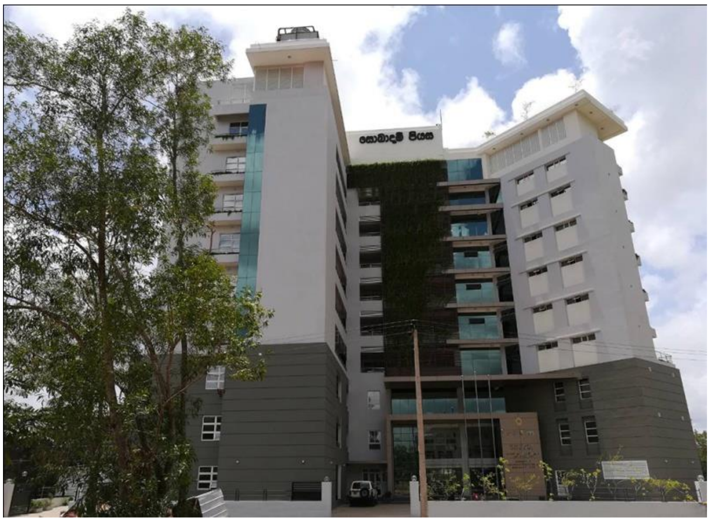
National Award for Construction Performance 2017

Category III - valued between Rs: 100 million & 500 million

Widening of Bridge No. 2/1 on Narahenpita –

Nawala – Nugegoda Road

NATIONAL AWARDS FOR GREEN CONSTRUCTION - 2017



Merit Award - 2017

Category I - value exceeding Rs: 300 million

Design & Construction of National Environmental Secretariat for Ministry of Mahaweli Development and Environment at

NATIONAL AWARDS FOR ENVIRONMENTAL FRIENDLY INNOVATIVE CONSTRUCTION RELATED TECHNOLOGY - 2017

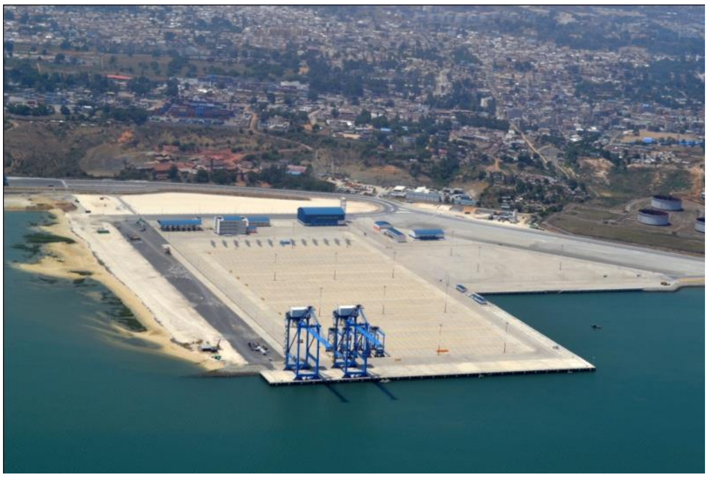
National Awards for Environmental Friendly Innovative Construction Related Technology -2017

Expanded Polystyrene Light Weight Concrete Sandwich Panel

NATIONAL AWARDS CONSTRUCTION PERFORMANCE - 2017

(Building & Civil Engineering)

(Awards to Overseas Projects by Domestic Construction Contractors)



National Award for Construction Performance 2017

Construction of Building & Associated Works - Mombasa Port Development Project, Kenya

by Sanken Overseas (Pvt) Ltd.

National Award for Construction Performance 2017

Construction of Channel and Aqueducts

(from 1+100 to 2+047),

Forebay & Spillway, Power House, Tailrace & related Civil Works of Muvumbe Small Hydro Power Project, Uganda

National Award for Construction Performance 2017

Design & Construction of 120 room Amari Havodda Resort, Maldives

by Sanken Overseas (Pvt) Ltd.

CIDA AWARD OF EMINENCE

- ***CIDA Award of Eminence - 2016***

Chartered Architect

Prof. Chitra Weddikkara

for her life time contribution
to the upliftment of the
Construction Industry &
the profession of Architecture

Professional experience encompasses fields of Architecture, Quantity Surveying, International Construction Management Dispute resolution, Arbitration, Value management and Project Management.

Work experience also encompasses working as the Professor of Building Economics, Head of Department of Building Economics, Dean, Faculty of Architecture, University of Moratuwa Sri-Lanka and Senior lecturer in University of Western Sydney in New South Wales Australia, President of the Institute of Quantity Surveyors, President Sri Lanka Institute of Architects /Chairman/ Member of many technical and advisory committees of the Sri Lanka Institute of Architects and the Government of Sri-Lanka

ACADEMIC QUALIFICATIONS

- Ph.D. in Dispute resolution College Law, Murdoch University Perth Western Australia
- Master of Science Building Studies, Curtin University of Technology, WA
- Bachelor of Applied Science in Quantity Surveying, Curtain University of Technology, Perth, Western Australia
- Associate Diploma in Quantity Surveying Western Australian Institute of Technology, Perth, Western Australia.
- Associate ship in Architecture , Western Australian Institute of technology, WA
- Bachelor of Science in Built Environment University of Colombo Sri Lanka
- Part I Royal Institute of British Architects, University of Colombo, Sri Lanka
- Certificate in International Construction Management, Sweden

PROFESSIONAL MEMBERSHIPS

- Fellow of the Institute of Architects Sri- Lanka (FIA) SL Sri Lanka
- Assoc member of Royal Australian Institute of Architects (ARAIA)
- Fellow member of the Australian Institute of Quantity Surveyors (FAIQS)
- Fellow of Royal Institute of Chartered Surveyors (FRICS) 199
- Fellow of the Institute of Quantity Surveyors (FIQS) SL Sri Lanka 1998
- Mediator- LEADR' Centre for Commercial Mediation, Australia
- Fellow Member of Institute of Project Mangers (SL)

OTHER COMMITMENTS

- Member of the National Procurement Commission
- Member of the CIDA Advisory Board
- Vice President of Chamber of Construction Industry

- ***CIDA Award of Eminence - 2016***

Eng. C H De Tissera

for his life time professional contribution

to the upliftment of the

Construction Industry

- B Sc. (Engineering) – University of Sri Lanka - 1965
- Post Graduate Diploma in Housing Planning & Building – Bowcentrum (IHS) Rotterdam, Holland - 1969
- M Sc. (Soil Mechanics & Foundation Engineering) - University of New Castle upon Tyne, U.K - 1979
- Post Graduate Certificate course in Construction Management for from University of California, Berkeley, USA - 1982
- Member, Institution of Engineers, Sri Lanka
- Director General – ICTAD – 1986 to 1989
- Additional Secretary (Technical), Ministry of Urban Development, Housing & Construction - Dec. 1989 to Aug.
- Additional Secretary (Development), Ministry of Science & Technology - Aug. 1999 to May 2001
- Project Management Consultant - JBIC and UNDP - May 2001 to Feb. 2005
- Habitat Programme Manager, UN-Habitat Sri Lanka - March 2005 to December 2008
- National Consultant to UN-Habitat Sri Lanka - January 2009 to Sept 2009
- Free- lance Consultant - UN-HABITAT Projects - Oct.2009 to date
- Chairman - Sri Lanka Land Reclamation and Development Corporation
- Director General - National Building Research Organisation (NBRO)
- Chairman – CIDA - Feb. 2015 to April.2016

- ***CIDA Award of Eminence - 2016***

Eng. K L S Sahabandu

for his life time contribution to the upliftment of the Construction Industry & the profession of Engineering

- **B.Sc. Eng. Hons**, University of Peradeniya, Sri Lanka, 1980
- **Pg. Dip. (Hydraulic Engineering)**, University of Moratuwa, Sri Lanka, 1985
- **M.Sc. (Structural Engineering)**, University of Newcastle upon Tyne, UK, 1988
- **Chartered Engineer,** UK, 1985
- **Chartered Engineer,** Sri Lanka, 1985
- **M.I.C.E. (UK)**, 1985
- **M.I.E. (S.L.)**, 1985
- **M.S.S.E (S.L.)**, 1993
- **M.Cons.E (S.L.)**, 2004
- **F.S.S.E. (S.L.)**, 2015
- **Visiting Lecturer**-City School of Architecture, Colombo, 2005 to date
- **President**, Society of Structural Engineers, Sri Lanka, 2016
- **Vice President**, Sri Lankan Geotechnical Society, 2015 to date
- **Vice President**, National Committee of Large Dams, Sri Lanka, 2006 to date
- **Chairman**, Subcommittee for preparing Design Guidelines at Disaster Management Centre, 2011-2014
- **General Manager**, Central Engineering Consultancy Bureau (CECB), 2013 to date
- **Director**, Central Engineering Services (Pvt) Ltd. (CESL), 2011 to date
- **Director**, Mahaweli Consultancy Bureau, 2015 to date
- **'Award for the Best Paper'** at the "**7th International Conference on Inspection, Appraisal, Repairs & Maintenance of Structures**" organized by the University of Nottingham and the Institution of Structural Engineers, UK in September 2001 for the paper on "**Damage Assessment and Repair Techniques used in Bomb and Fire Damaged Central Bank Building in Sri Lanka** ".

- **'Patrick Parson's Prize – 1987/88' – For the best all-round academic record in the M.Sc. course in Structural Engineering –** University of Newcastle upon Tyne - UK.
- **'NECTTA/TRADA Structural Timber Award Competition – 1988' - UK - Second Place.**

- ***ICTAD Award of Eminence - 2014***

Eng. S A Karunaratne

for his life time contribution to the upliftment of the Construction Industry & the profession of Engineering

- BSc Eng. (University of Peradeniya) 1967
- MICE (UK) 1970
- Chartered Engineer
- MIE (SL) 1971
- MIStructE (UK) 1974
- FIStructE (UK) 1990
- FIE (SL) 1990
- HF (SSE-SL) 2009
- HLF (SL) 2014
- President SSE (SL) 2004, 2005, 2006, 2007, 2008
- Visiting Lecturer (MSc Structural – University of Moratuwa) 2006 to 2015
- Chairman - EuroCodes National Annexes (SLSI)
- Managing Director – STEMS Consultants (Pte) Ltd

- ***ICTAD Award of Eminence – 2014***

Archt. Jayantha Kithsiri Perera

for his life time contribution to the upliftment of the Construction Industry & the profession of Architecture

- FIA(SL) 1992

- M.Sc.(Arch.), B.Sc (BE)
- SLIA First Membership 1981
- President SLIA 2007/2009
- Chairman SAARCH 2009/2012
- Deputy Chairman ARCASIA Zone A 2010/2011
- Chair Communication CAA 2014/2017
- Director UIA Work Programme on Responsible Architecture 2014/2017

- ***ICTAD Award of Eminence – 2014***

Dr. (Eng.) Ananda Ranasinghe

for his life time contribution

to the upliftment of the

Construction Industry in General

- PhD, MEng, MTech, LLM, BScEng,
- CEng, FIStructE, FICE, FIESL,MSSE,
- Attorney-at-Law
- President IESL 2011/2012

- ***ICTAD Award of Eminence – 2013***

Eng. W J R De Mel

for his life time contribution

to the upliftment of the

Construction Industry & the profession of Engineering

- BSc Eng, C Eng
- M.Sc.(Construction Management)
- MICE, MIE

- ***ICTAD Award of Eminence – 2011***

Dr. E M G de Zylva

for his life time professional contribution

to the upliftment of the

Construction Industry

- MBA (Const. Mgt.) USA
- Doctoral Fellow – Institute of Professional Financial Managers (UK)
- Professional Member – Dispute Board Federation (Geneva)
- Fellow – Institute of Dispute Management Professionals (SL)
- Hon. Fellow – Institute of Quantity Surveyors (SL)
- Fellow – Institute of Project Managers (SL)
- Member Board of Governors of the National Arbitration Center (SL)
- Lecturer/ Examiner (Arbitration Diploma Courses) of the Institute of Commercial Law & Practice (SL)

- ***ICTAD Award of Eminence – 2011***

Vidyajyothi Prof. Lakshman Alwis

for his life time contribution

to the upliftment of the

Construction Industry & the

profession of Architecture

- B. Arch. (Melbourne) 1967
- ARAIA 1967
- RIBA (UK) 1968
- FIA (SL) – 1980
- Chartered Architect
- D. Sc (Honaris Causa) University of Moratuwa
- PG Diploma Architectural Conservation of Monuments & Sites, ICCROM Rome 1983
- President SLIA 1987/1988, 1988/1989
- Dean Faculty of Architecture, University of Moratuwa 1991 to 1999
- Professor of Architecture, University of Moratuwa 1991 to 2004

- Chairman, Board of Education, ARCASIA 94/95, 95/96
- President of ICOMAS 1995
- Director Conservation of Cultural Triangle Project, Dambulla 1995
- President, Rotary Club of Colombo 1996/1997
- Deputy Chairman ARCASIA 2001 – 2002
- Chairman, ICTAD 2004 to 2007
- Honorary Fellow, SLIA 2005
- Vidyajyothi (National Award) by the President of Sri Lanka 2005
- ICTAD Award of Eminence 2011
- SLIA Gold Medalist 2013
- Principal Architect / Chairman – Design Consortium Ltd

- ***ICTAD Award of Eminence – 2011***

Mr. H D Chandrasena

for his life time contribution

to the upliftment of the

- Fellow of the Institute of Quantity Surveyors Sri Lanka (F.I.Q.S. SL)
- Fellow of the Australian Institute of Quantity Surveyors (F.A.I.Q.S.)
- Fellow of the Royal Institution of Chartered Surveyors (F.R.I.C.S.)
- Fellow of the Institute of Dispute management Professionals (F.I.D.M. P)
- Associate of the Institute of Arbitrators Australia A.I.Arb (Aus) 1979
- Present Position – Chairman, Cost Consultancy Services (Pvt.) Ltd. Rajagiriya.
- Previous Position Asst. General Manager Consultancy Services and Chief Quantity Surveyor – State Engineering Corporation. Sri Lanka.
- Representative for Sri Lanka of the Australian Institute of Quantity Surveyors.
- Member, Board of Governors Sri Lanka National Arbitration Centre.
- Executive Committee Member Chamber of Construction Industry Sri Lanka.
- Past President Institute of Quantity Surveyors Sri Lanka
- Visiting Lecturer and Lesson Writer Open University Sri Lanka
- Member of the Dispute Adjudicators Panel – Institute for Construction Training and Development – Ministry of Housing Construction and Common Amenities.
- Member of the Executive Committee of the Institute of Dispute Management Professionals-Sri Lanka

- External Examiner Royal Institution of Chartered Surveyor Accreditation Panel 1998-2003 & 2008– to date (Department of Building Economic University of Moratuwa)
- Member of the main Planning Committee of the Urban Development Authority representing the Chamber of Construction Industry Sri Lanka.
- Visiting Lecture of Board Member of the Faculty of Architecture University of Moratuwa. (1974 to 1998)
- Member of the Consultative Committee and Steering Committee Member (Technical Publications) - Institute for Construction Training and Development (ICTAD)
- Member of the Construction Cluster of the National Council for Economic Development.
- Member of the Committee for Drafting Procedure for Contract Adjudication and Setting up of National Adjudication Centre- Sri Lanka.

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නිවාස හා ඉදිකිරීම් අමාත්‍යාංශය

ඉදිකිරීම් කර්මාන්ත සංවර්ධන අධිකාරිය

පාසැල් හැර යන සිසුන් සඳහා තුන් අවුරුදු පූර්ණ කාලීන පාඨමාලාවක් නොමිලේ

ඉදිකිරීම් යන්ත්‍රෝපකරණ නඩත්තුව පිළිබඳ පැවැත්වෙන වාර්ෂික පුහුණු පාඨමාලා

- ඉදිකිරීම් යන්ත්‍රෝපකරණ කළමනාකරණය
- ඉදිකිරීම් යන්ත්‍රෝපකරණ නඩත්තු අධීක්ෂණය (ද්‍රාවබල සහ සම්ප්‍රේෂණ පද්ධතිය)
- ඉදිකිරීම් යන්ත්‍රෝපකරණ නඩත්තු අධීක්ෂණය (එන්ජිම සහ මෙකාට්‍රොනික් පද්ධතිය)
- ද්‍රාවබල සහ මෙකාට්‍රොනික් පද්ධති නඩත්තුව
- ඉදිකිරීම් යන්ත්‍රෝපකරණ විද්‍යුත් පද්ධති නඩත්තුව
- ඩීසල් එන්ජින් නඩත්තුව
- ද්‍රාවබල පද්ධති නඩත්තුව
- ඩීසල් ජෙනරේටර් නඩත්තුව
- ස්ටියරින් බ්‍රේක් සහ ක්ලච් පද්ධති නඩත්තුව
- ටෝක් කන්වර්ටර් සහ සම්පීඩන පද්ධති නඩත්තුව
- ඉදිකිරීම් යන්ත්‍රෝපකරණ මූලික ඉලෙක්ට්‍රොනික් සහ මෙකාට්‍රොනික් පද්ධතිය
- ජල පොම්පය සහ වායු සම්පීඩන පද්ධති නඩත්තුව
- ඉදිකිරීම් යන්ත්‍රෝපකරණ සේවා කිරීම
- මූලික ඉදිකිරීම් යන්ත්‍රෝපකරණ කාර්මික පාඨමාලාව (තුන් අවුරුදු පූර්ණකාලීන)

**ශ්‍රී ලංකාවේ ඉදිකිරීම් යන්ත්‍රෝපකරණ තාක්ෂණික ශිල්පි පුහුණුවට ඇති
එකම රාජ්‍ය ආයතනයෙන් ජාත්‍යන්තර සුදුස්සෙකු වන්න.**

ඉදිකිරීම් යන්ත්‍රෝපකරණ පුහුණු මධ්‍යස්ථානය

අංක. 17, ඩී.පී. විජේසිංහ මාවත, පැලවත්ත, බත්තරමුල්ල.
ටෙලි. 011 2784413 / 2786829
ෆැක්ස් : 011 2784411
ඊ-මේල් : cetrac@sltnet.lk   වෙබ් : www.cida.lk

CONSTRUCTION INDUSTRY
DEVELOPMENT AUTHORITY

OTC

නිවාස හා ඉදිකිරීම් අමාත්‍යාංශය

ඉදිකිරීම් කර්මාන්ත සංවර්ධන අධිකාරිය

1982 වසරේ ලෝක බැංකු ආධාර මත ආරම්භ කරන ලද ගල්කුලම ඉදිකිරීම් යන්ත්‍රෝපකරණ මෙහෙයුම් ශිල්පි විදුහල මෙහෙයුම් ශිල්පීන් පුහුණු කිරීම සඳහා ශ්‍රී ලංකාවේ ඇති එකම රාජ්‍ය ආයතනයයි.

දේශීය සහ විදේශීය ඉහළ රැකියා ඉල්ලුමක් ඇති ඉදකිරීම් යන්ත්‍ර ක්‍රියාකරුවන් පුහුණු කිරීම සදහා පාඨමාලා පවත්වයි.

මෙම ආයතනයේ පාඨමාලා හදාරා පුහුණුව අවසන් කරන ආධුනිකයින් සහ දැනට වෘත්තියේ යෙදී සිටින අය හට දක්ෂ ඉදිකිරීම් යන්ත්‍ර ක්‍රියාකරුවකු වී නිපුණතා ශිල්පී සහතිකය සහ හැඳුනුම්පතක් ද අවශ්‍ය න්‍යායික දැනුම හා ප්‍රායෝගික පුහුණුව කාර්යශූර ආචාර්යවරුන් හා නිලධාරීන් විසින් ලබාදේ.

රාජ්‍ය ආයතනයක් වශයෙන් කිසිම ලාභ පරමාර්ථයකින් තොරව රජය විසින් විශාල වියදමක් දරා නේවාසික පහසුකම් සමග මෙම පුහුණු කටයුතු සිදුකරන අතර, පුහුණු ලාභියාගෙන් අයකරනු ලබන්නේ පුහුණුව සඳහා වැයවන පිරිවැයෙන් ඉතා සුළු කොටසකි.

පාසල් හැරගිය රටේ දහසක් දුවා දරුවන්ට ගල්කුලම බරවාහන මෙහෙයුම් ශිල්පි පුහුණු මධ්‍යස්ථානය මෙම ක්ෂේත්‍රයේ ජාත්‍යන්තර පිළිගැනීමකින් යුතු නිපුණතා සඳහා මග විවර කර දී තිබේ.

ශ්‍රී ලංකාවේ ඉදිකිරීම් යන්ත්‍රෝපකරණ මෙහෙයුම් ශිල්පි පුහුණුවට ඇති
එකම රාජ්‍ය ආයතනයෙන් ජාත්‍යන්තර සුදුස්සෙකු වන්න.

ඉදිකිරීම් යන්ත්‍රෝපකරණ මෙහෙයුම් ශිල්පී පාඨමාලා

- මූලික ඉදිකිරීම් යන්ත්‍ර නඩත්තු ශිල්පය
- සැහැල්ලු ඉදිකිරීම් යන්ත්‍ර මෙහෙයුම් ශිල්පය
- ට්‍රැක්ටර් පුහුණු පාඨමාලාව
- ගල් රෝලර් පුහුණු පාඨමාලාව
- ලෝඩර් බැකෝ
- වීල් ලෝඩරය
- ඒක්ස්කැවේටරය
- මෝටර් ග්‍රේඩරය
- ඩෝසරය
- ජංගම දොඹකරය
- ඩම්ප්ට්‍රක් රථය
- යන්ත්‍රෝපකරණ ප්‍රවාහකය
- ෆෝක්ලිෆ්ට් ට්‍රක්
- ස්කිඩ් ලෝඩරය
- බූම්ට්‍රක්/ක්‍රේන්ට්‍රක්
- ඉදිකිරීම් යන්ත්‍ර කළමනාකරණ පාඨමාලාව

ඉදිකිරීම් යන්ත්‍ර මෙහෙයුම් ශිල්පි විදුහල

ගල්කුලම, අනුරාධපුර.
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