MANAGING THE SOCIO-ECONOMIC IMPACTS DUE TO COMPACTION OPERATIONS DURING CONSTRUCTION OF SOUTHERN EXPRESSWAY

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DECLARTION

I hereby certify that this dissertation does not incorporate, without acknowledgement, any material previously submitted for a Degree or Diploma in any University and to the best of my knowledge and belief, it does not contain any material previously published or written by another person or myself except where due reference is made in the text. I also hereby give consent for my dissertation, if accepted, to be made available for photocopying and for interlibrary loans, and for the title and summary to be made available to outside organizations

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16th December 2011

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Abstract

Southern expressway is the first expressway project started in Sri Lanka. It is expected to help reduce poverty in Southern region, integrate Southern region in to the Country's economic mainstreams, and promote regional development as well as reduce the travel time between the capital city and southern region.

The main purpose of this study is to identify the socio-economic impacts during compaction activities while construction of the southern expressway in Sri Lanka, highlight its impact on the people's lives who live near the highway trace and to forward recommendations for minimization of such disturbances. A questionnaire survey was carried out among the professionals engaged in the project and also nearby households along the trace to identify the influence and the effects of compaction. Altogether 1,547 houses were inspected. In addition, persons who are holding the key positions of the project were interviewed. A crack survey was carried out before the compaction activities on the expressway trace as well as after the compaction activities. After that comparison of a pre- and post-crack survey was done to determine the actual damage to the houses located near the trace due to compaction activities.

After analyzing all the data it is clear that houses which are located close to the expressway trace are considerably damaged due to the construction activities. Vibration levels were monitored by the government institutes regularly at nearby houses. Contractor is responsible for the damage due to higher vibration. Some houses have not been built to the proper standards and some are much old to withstand higher vibration levels. Prior to construction activities of the southern expressway an Environmental impact assessment (EIA) was done by University of Moratuwa in 1999. Mitigation proposed in the EIA has not satisfactorily been implemented as regards to the impact of vibration due to compaction operations and any sufficient attention had not been paid regarding the ground vibrations. Those are the major shortcomings which were identified in this research. Some of the unrealistic designs of the projects were proposed that led to most of the project delays and more of the cost over-runs.

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CHAPTER ONE

1 INTRODUCTION

1.1 What is a highway?

A highway is a main road for travel by the public between important destinations, such as cities and states. Highway designs vary widely and can range from a two-lane road without margins to a multi-lane. Any classification of a road as a "highway" and therefore any statistics about the total length of a highway network are purely subjective. Some highways, like the Pan-American Highway or the European routes, bridge multiple countries. Australia's Highway 1 is the longest national highway in the world at over 20,000 km (12,000 miles) and runs almost the entire way around the continent. Highways are not always continuous stretches of pavement. For example, some highways are interrupted by bodies of water, and ferry routes may serve as sections of the highway.

1.2 Southern express way

Sri Lanka has an extensive road network but most roads were built about 50 years ago and do not possess the capacity to cope with the increasing traffic volumes. Therefore there is an urgent need to improve the capacity and efficiency of the road network to meet the growing transport requirements of the country and avoid the road network becoming an impediment to development. The Southern Transport Development Project (STDP) is Sri Lanka's first major expressway to be built since independence in 1948. Also this is the longest Expressway out of the proposed Expressway Network. This is run from Kottawa to Matara and also includes Galle port access road. It is a controlled access expressway with 8 interchanges at Kahathuduwa, Bandaragama, Dodangoda, Welipenna, Elpitiya, Baddegama, Akmeemana, and Weligama.

Southern Transport Development Project is one of the highest priority infrastructure investments with several project components which are financed by different donors. Asian Development Bank (ADB) and Japan Bank for International Cooperation (JBIC) are the main funding agencies for this project.

There are two major products in this project and principal one is to construct a 126 km new expressway linking Kottawa in Colombo suburbs to Godagama, Matara in Southern Province of Sri Lanka. The project constructions have divided into two sections for financing purposes. The first section is from Kottawa to Kurudugahahetekma (66.5 Km) is funded by Japanese Bank for International Corporation (JBIC). The second section is from Kurudugahahetekma to Matara, Godagama (59.5 Km) and Galle port access road (5 Km) are funded by Asian Development Bank (ADB). Summary of the project can be shown as follows.

Table 1-1. Summary of the southern expressway project

Total Length	131 km
Section I - Funding by JBIC Package I - From Kottawa to Dodangoda Package II - From Dodangoda to Kurudugahahetekma **Section II- Funding by ADB** From Kurudugahahetekma to Matara Godagama Galle Port Access Road	35.0 km (4 Lanes) 31.5 Km (4 Lanes)
Executing Agency	Ministry of Highways
Implementing Agency	Road Development Authority- Western Province
Final Stage	Widening to 6 lane
Estimated Cost - ADB section JBIC Section	Rs.11.5 Billion Rs.17.5 Billion
Design Speed	120 km/h

ADB Section Supervision Consultancy Section Construction Contract	Halcrow Group Ltd. (UK) with Roughton International (UK) and Engineering Consultant Ltd.(SL) Kumagai Gumi Co.Ltd (Japan)
JBIC Section Supervision Consultancy Section Construction Contract Package – I Package - II	Pacific Consultant International with Resources Development Consultant (RDC) China Harbor Engineering Company Taisei Corporation (Japan)
Intersections Locations	1. Kottawa 7.Baddegama 2. Kahatuduwa 8. Pinnaduwa 3. Gelanigama 9. Deegoda 4. Dodangoda 10.Kokmaduwa 5. Welipanna 11. Godagama 6. Kurundugahetekma

1.2.1 Locations of the Southern expressway Project

Figure 1-1 Locations of the project

1.2.2 The main objectives of constructing express way from Colombo to Matara

- Reduce the poverty in Southern region, integrate Southern region in to the Country economic mainstreams, and promote regional development.
- Reduced travel times, this is especially important for commercial vehicle traffics, which is time sensitive.
- Provide an expressway to act as a catalyst in encouraging and attracting industries and services for the Economic and Social development of the region.
- To promote inter-regional transport facilities by developing this road, considering it as a major component of the proposed Expressway network.

1.3 The social environment of the area

The social structure of the project area is that of predominantly rural environment, where the economy is mainly agriculture. There are also a few townships to cater to the rural community. The majority of people living in the project area are small agricultural produces belonging to traditional families who have been living in their ancestral area. These families have to extended network of kinship relationships based on the consanguinity or matrimony. Therefore such families have to be considered as aggregate social units sharing common interest for their survival and progress. The ethnic and religious composition of the population in the project area was found to be consistently a majority Sinhala/Buddhist one with the less than 5% of the population belonging to other ethnic groups and religious. An inequality based on the distribution of income/wealth is very significant in a large number of locations.

The life style of people in the project area is simple and it is not far different from what could be seen in any peasant community in the rest of the country. The most valuable properties for them are the land and the house. Nearly one third of the population is employed in agricultural sector, the majority crops grown in the project area being tea, rubber, coconut and paddy. Other forms of employment in the area are state or private sector employment, self-employment, small-scale business activities and casual labour.

1.4 Social and environmental effects when operating an expressway

By reducing travel times relative to arterial streets, highways have a positive effect upon balance of leisure or productive time through reduced commute and other travel time. However, highways have criticisms, partially due to being an extended **linear source** of **pollution**:

- **Roadway noise**: Highways generate more roadway noise than arterial streets due to the higher operating speeds. Therefore, considerable noise health effects are expected from highway systems. Noise mitigation strategies exist to reduce sound levels at nearby sensitive receptors.

- **Air quality issues**: Highways may contribute fewer emissions than arterials carrying the same vehicle volumes. This is because high, constant-speed operation creates an emissions reduction compared to vehicular flows with stops and starts. However, concentrations of air pollutants near highways may be higher due to increased traffic volumes. Therefore, the risk of exposure to elevated levels of air pollutants from a highway may be considerable, and further magnified when highways have traffic congestion.

- **New roads can create new traffic**: sometimes referred to as induced demand. If not accurately predicted at the planning stage, this extra traffic may lead to the new road becoming congested sooner than anticipated. More roads add on to car-dependence. This may mean that by building a new road, there is only short-term mitigation of traffic congestion. In the long-term, even more cars may take over the excess road space - which exacerbates the problem. The induced demand phrase is often used as a catch-all phrase by proponents of freeway revolt.

During the construction phase, residents may be disrupted and inconvenienced by detours, local road closures, dust, noise, heavy equipment on existing roads, changes in the level of service, safety hazards, and interference with emergency services. Occasionally, there is vibration damage to near-by structures. However, residents may benefit from construction employment.

When the roadway is opened for use, positive impacts result for many residents. Travel time, accidents and inconvenience to users generally decrease. The roadway increases access to jobs, schools, stores, recreation and other community services and amenities. These effects can be reflected in increased land values. However, there may be negative impacts for some residents living near the roadway. These include increased noise, pollution and aesthetic impacts. Some of these impacts can be mitigated.

1.5 Problem statement

Southern highway is running from Kottawa to Matara mainly going via rural areas. There are some serious effects to the environment and the general public that are living nearby highway trace. Even though EIA (Environmental Impact Analysis) has done in the planning stage of the project by environmental specialists to identify the environmental impacts of the project and has proposed the ways to reduce the damages there are some serious affects to the environment as well as the general public. In the EIA they haven't considered the impacts to the houses/buildings due to the construction process. Followings are some severe effects causes by the construction of highway trace.

- Damages due to excessive vibration in blasting and compaction activities
- Cracks due to vibrations, compactions and blasting activities.
- Erosion due to construction activities
- Shortcoming with planning stage (considering EIA) and the actual results

Therefore this study attempts to identify the intensity of the damage, study the reasons and problems regarding construction of southern highway with following objectives.

1.6 Objectives of the study

General Objective

- To analyze the socio economic impacts due to compaction operations during the construction of southern expressway

Specific Objectives

- To evaluate that how the compaction activities affect to public and environment.
- To compare the findings with what was proposed in the EIA (post evaluation of the EIA)
- To Identify the planning short comings in predicted impacts
- To analyze the reactions that was taken by environmental engineers, environmental organizations and general public.
- To suggest the proposals for preventing any hazards for future development

1.7 Scope of the study

The research was carried out with the help of in an environmental institutions, environmental engineers and public which are related to the construction of expressway in southern area, Sri Lanka. How does this construction affect to the environment and public's day today activities or future activities.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Southern expressway

Southern expressway will pass through a significant part of the urban/ rural areas of western and southern provinces and in doing so affects many different communities. The social and demographical profile of the project area has a strong contrast between established suburban and rural areas and significant new areas for residential development. The occupational mix for the project area indicates higher percentage of agricultural based and also to some extends working on government and private sectors. Public transport is the dominant mode of transport in this project area while considered as the low socio-economic area with compared to the country.

2.2 Feasibility study

A feasibility study should be done by suitable experts (engineers, Economist, Environmentalist, Sociologist, etc...) before implementing any project to evaluate economical and social returns from the project. In addition environment impact assent also be done by the environmental specialist to minimize public hazards and environmental problems. After finalizing these reports a team of experts should study report and should be taken a decision for implementing the project.

Then these experts are concerned with works developed to protect and promote public health, improve the environment, and prevent degradation of land, water and air. Their practice includes surveys, reports, designs, reviews, management, operation and investigation of such works.

The objective of these works are protecting public health and controlling environment. Have to deals with treatment and distribution of water supply, collection treatment, control of pollution in surface and underground waters, limitations on exposure to radiation, limitations on noises and other environmental factors affecting the health, comfort, safety and well being of people and also environment.

The users of these reports and others take necessary decisions for continuing work or suspend work. Therefore accuracy of information is very important for all parties. The objective of preparing these reports is minimizing pollution, other environmental problems and overcome public matters.

After get approval from authorized institutions and take necessary precautions to prevent hazards construction can start. If construction management ignores these rules given by authorities they can suspend the work. Also they can take court actions against the construction.

But we cannot get 100% accurate solutions. So while doing construction we have to consider about public and environment. Sometimes we have to take mitigation actions to overcome ongoing issues which are occurred while construction progresses. Vibration due to construction activities especially in blasting and compaction is one of the major issues in southern expressway.

Earthborn vibration from vibratory compaction equipment can be described as single frequency continuous vibrations. Human perception of such ground vibrations is subjective and depends upon a number of factors. Damaged to structures causes by these earthborn vibrations can be categorized as either architectural or structural. Architectural damage is superficial damage such as hairline cracks in plaster walls or ceilings. While catastrophic damage to buildings from construction operations is always possible in nearby houses in southern express way .Some structural damage such as separation of masonry blocks and cracking in foundations may occur in cases where earthborn vibrations exceed threshold levels.

Central Environment Authority (CEA) has proposed vibration limit criteria, some intended to mitigate damages to structures and to limit human annoyance.

2.3 What is social impact assessment?

Social impact assessment has been applied in Sri Lanka to many provincial and federal projects and programs, including proposed energy generating stations, electricity transmission facility and highway construction assessments. More recently, a greater emphasis has been placed on SIA of the planning, design, construction and operation of proposed major roads projects.

Social impact assessment is a process of analyzing, predicting and evaluating the future social and economic effects of proposed policy, program and project decisions and actions on the well-being of people, and their businesses, institutions and communities. Its goal is to protect and enhance the quality of life by ensuring that potential socio-economic impacts are minimized and sound environmental decisions are made.

Social impact assessment involves identifying: significant potential positive and negative changes in peoples' cultural traditions and lifestyles, their physical and psychological health, their families, their institutions and their community. And, it identifies ways of avoiding, mitigating, enhancing or managing those changes (monitoring and impact agreements).

Importance of Social Impact Assessment:

- Predicts the nature and size of potential negative and positive effects on individuals , businesses and communities;

- Develops and implements appropriate recommendations and impact management measures to avoid or decease potential negative socio-economic impacts and enhance positive impacts;

- Identifies net social and economic impacts occurring after mitigation measures are applied, including roadway routing, design and operating conditions; and, Helps resolve public issues by working with the community to address the potential impacts.

The impacts on people, their community and way of life can occur during project planning, construction, and the "operational" phase when the roadway is in use. The impacts result from the introduction of specific project characteristics (e.g. divided highway, length of construction) and the local community and individual's response. This response depends largely on the community and individual characteristics (Example; level of automobile travel, community satisfaction).Although each situation presents some unique potential impacts, the following list illustrates the types of socio-economic impacts that could occur.

2.4 Ground vibration

Vibrations from pile driving and dynamic compactions are likely to be the largest vibrations caused by the construction. However, as the exact method of piling and location of dynamic compaction have both yet to be finalized, it is recommended that predictive models be used to determine the suitability of any piling and dynamic compaction rigs proposed for the available separation distances between where the construction activity is planned to take place and nearby buildings. These predictive models allow ground-borne vibrations to be estimated from drop mass and drop height.

Both these activities will have to be specifically addressed in the vibration mitigation plan, should it be decided that dynamic compaction and/or drop weight piling can be employed in the construction of the Southern Expressway project. It is also recommended that field measurements be made whenever both these types of construction activity take place to confirm the vibration levels predicted. This will minimize the likelihood of any structural damage being inflicted on existing buildings. If applicable, vibratory piling methods should be adopted as this will significantly reduce the likelihood of structural damage arising from piling operations.

2.4.1 Nonlinear and chaotic vibrations of dynamic compaction machines

Figure 2.1 shows the simple, non-linear soil-drum model for vibratory rollers and plates; this model is valid subject to the proviso that the excitation frequency is well above the resonance frequency for the frame-suspension elements. In this case, the static weight of the frame may be regarded as force acting statically on the vibrating mass. More advanced models take account of the horizontal and rotary movements as well as the frame vibrations for vibratory rollers, oscillation rollers and rollers with directed excitations.

The model in Figure 1 has been validated many times in practice, not only on tandem rollers for asphalt compaction but also for soil compaction with single-drum vibratory rollers. After adaptation to the geometry of a directed excitation, the present model can also be used to describe the nonlinear and chaotic vibrations of vibratory plates, trench rollers and rammers.

The essential nonlinearity of the soil-drum system arises due to the periodic loss of contact between the vibrating mass of the compactor (which is subject to circular excitation) and the surface below it, as soon as the maximum soil reaction force FS becomes larger than twice the static weight of the total mass of the machine. In the case of vibratory plates and rammers, this loss of contact is necessary for continued movement.

In analytical terms, the steady-state dynamic behavior of the soil-machine system from figure 1 can be described with the help of the equation of motion according to:

$$F_S = (m_f + m_d) g + m_e r_e \Omega^2 \cos(\Omega t \quad m_d x \qquad x_d = x \qquad (1)$$

Where;

F_S = soil-drum-interaction force (kN),

m_d = drum mass (kg),

m_f = frame mass (kg),

x_d = vertical displacement of the drum (m),

$m_e r_e$ = eccentric moment of unbalanced mass (kgm),.

The dot notation signifies the differentiation with respect to time.

The soil-drum interaction force can alternatively be written

Where;

k_S = soil stiffness (N/m),

c_S = soil damping (Ns/m).

Where;

i = phase lag between the generated dynamic force and the part of drum displacement with frequency if (°). Depending on the operational status, the vibration displacement has one or more frequencies:

Permanent drum-ground contact, linear:	i=1
Periodic loss of contact, nonlinear:	i=1, 2, 3 (Overtones)
Bouncing/rocking, sub harmonic:	i=1/2, 1, 3/2, 2, 5/2, 3

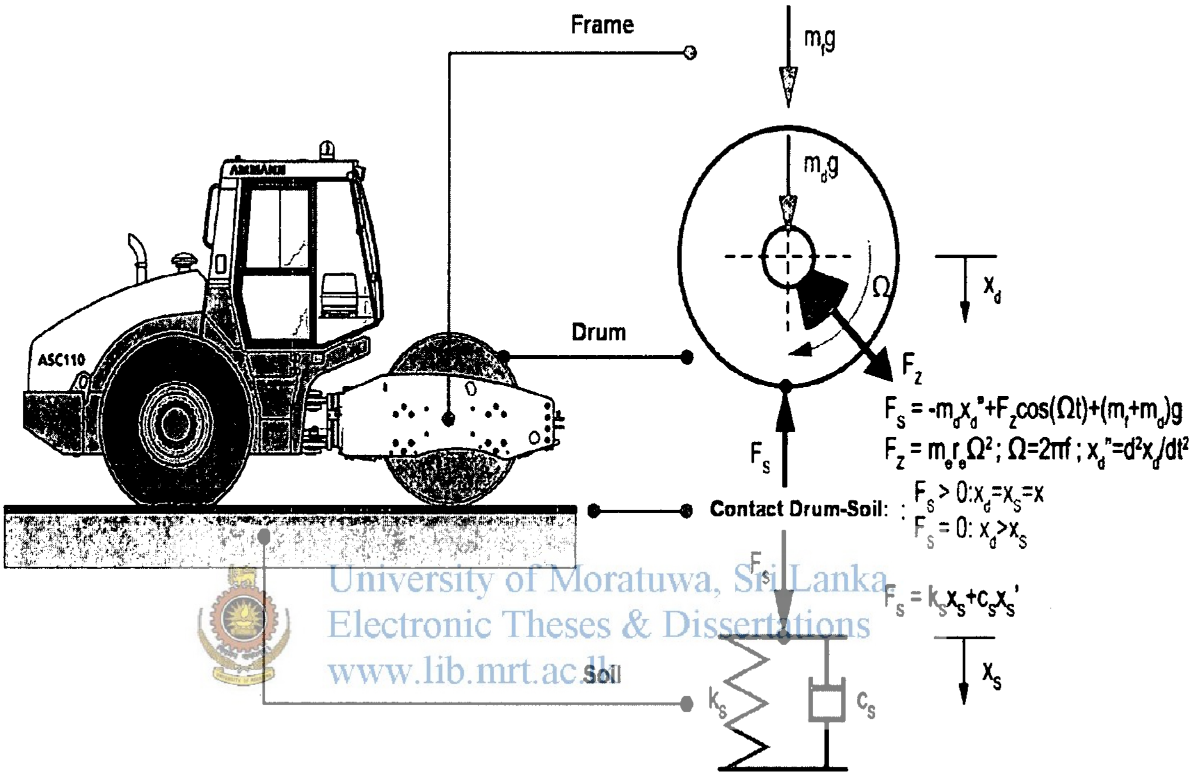


Figure 2-1 Analytical model of vertical vibration of a single drum roller (circular excitation).

This model is also valid for vertical deflection of vibratory plates (directed excitation)

2.4.2 Damage to the buildings caused by ground vibrations generated by vibratory compactors

Vibratory compactors generate ground vibrations which can be felt long distance from the machine. The same type of ground vibrations are produced by road traffic, pile driving, sheet driving and blasting operations. Ground vibrations over a certain magnitude can cause damage to buildings and other constructions.

A vibratory compactor is operating on the ground generates pressure (compression) and shear waves called body waves as well as the surface waves (primarily Rayleigh waves). The surface waves and the wave types which are of primary concern for structures on or near the surface of the soil. The amplitudes of the surface waves decreases rapidly as the distance from the vibrator increases, to a large extent depending on the decrease in wave energy caused by the circular propagation of the waves.

A wave motion is characterized by frequency and amplitude. It has been generally accepted that the risk for damage is determined by the maximum velocity of the ground vibrations, which can be calculated according to the formula.

$V = 2\pi f \cdot s$

Where;

V=maximum velocity during wave motion mm/s

f= frequency, Hz

s= amplitude, mm

As an approximate and general rule , it has been found that ground vibration generated by compaction activities with a velocity higher than 2 mm/s (on the structure foundation) cause damage to the buildings. Also note that the vibrations in building foundations are less than the surrounding ground. If the wave velocities in the ground, just outside and inside a building are measured simultaneously, the wave velocities in the building foundation are 2 to 5 times lower. When Vibration is measured during in compaction activities, the value of the vibration can be change place to place along the highway trace. Following factors are mainly associated with the vibration levels

- Types of the soil and soil profiles vary to a large degree. The strong vibrations can be found in silt and clay with high water content
- Ground vibrations may be stronger than during dry conditions while compare with the wet condition of the soil
- Types of foundations, as well as structural designs and condition of the building can be affected for the vibration level
- Resonance phenomena in different parts of the building such as the chimney –shift may increase the risk of damage to the building
- If the stress limit in a material is already approached, as it often the case in plastered walls, very small additional stress may cause damages.
- Start and stop of the vibrations temporary increase the ground vibration as the resonance frequency of the system vibrator soil has to be passed. resonance vibrations in building structures can also be developed. The vibration should not start or stopped near the buildings.

2.5 Vibration Control and Monitoring

Vibration producing activities (such as blasting, pile driving, vibratory compaction, pavement breaking or operation of heavy construction equipment) are common in construction projects. Four levels of vibration control can be provided on a project, depending on things such as structure susceptibility to damage, proximity to vibration producing activities, local concerns, or district policy. The "levels" can briefly be defined as follows:

Level 1: No specific mention in contract of possible problems or controls. On a statewide basis, this is most common for minor or small quantities of pavement breaking or pile driving, when they are not in proximity to occupied structures or sensitive receptors.

Level 2: Alert contractor to possible problems by brief description in the special provisions. Vibration levels and monitoring are at the discretion of the contractor, and the contractor is responsible for all damage caused by his activities.

Level 3: Detail concerns and require the contractor to do a prescribed condition survey and to employ a qualified vibration specialist to establish a safe vibration level and monitor the vibrations. As an alternative, a vibration level may be set by the Department, such as the "Geological survey and mines bureau". It may also be appropriate to use experienced based vibration criteria. The contractor is still responsible for any problems.

Level 4: State takes lead role and has consultant(s) do a damage susceptibility study to establish vibration control limits, and a preconstruction condition survey for each structure. The State also takes responsibility for vibration monitoring during construction to insure compliance with vibration control limits. At this level, the State assumes some responsibility for damage to structures if the established vibration limits are not exceeded by the contractor. The degree of responsibility depends on the vibration specification - most vibration specifications are aimed at avoiding structural damage, leaving the contractor responsible for any cosmetic damage (e.g. plaster cracks, broken windows, etc.) and keeping residents/occupants informed and "happy".

Table 2-1. Maximum Permissible Vibration Levels

Activity	Frequency/ type	Permissible Vibration in PPV (mm/Sec)	ABOP dB (L)
Construction activity / vehicle movement	10 – 50 (Continuous)	2.0	
Rock Blasting with multi bore holes and with delay detonators	Impulsive	5.0	120

2.6 Cracking in Buildings

Cracking first occurs in buildings immediately after construction or over a period of several years, depending upon the methods and materials used in construction and change in ground characteristics caused by, for example, the removal of trees. Buildings have different life spans or time periods before deterioration or damaged occurs. This time period depends upon the stresses to which the building has been exposed as well as the residence of the building materials to physical and chemical effects.

Heat, moisture, settlement, occupational loads, material creep and chemical changes all cause movements in the building, in an optimized design, the buildup stress concentrations in the structural elements should be minimized. If the design does not permit adequate relaxation of these stress concentrations, then cracks will develop which indicates where movement joints are required or alternatively where further support or reinforcement is needed. Thus cracks normally exist to varying degrees in buildings not subjected to vibration and are not in themselves, an indication of vibration-induced damage. There are many reasons why buildings crack are care is required to ascertain the truth cause.

A building not exposed to major external disturbances such as vibration, there exist a time state of cracking due to natural ageing. This is natural cracking rate can be significantly increased by an external disturbances trigging cracks instantaneously, which can only be detected by a recovery of building cracks immediately before and after the disturbance. A small increase in cracks or crack length however should not be taken as damage due to any imposed vibration. Buildings so expand and contract preferentially along existing weaknesses (cracks) between day time and night time and also seasonally. This continually varying expansion and contraction will return normal repair and repainting to the previous cracked state within several years or even months.

Wall and ceiling lining material rather than the main building components are often the most sensitive to imposed vibration. For cracking to occur, the vibration induced strain so that the critical strain of a wall covering material is exceeded. The lowest critical strain is associated with old plaster and lath walls while the paper backing on gypsum- type wallboard has the highest resistance to imposed strain, although cracks can frequently occur at the joints between boards.

2.6.1 Age and existing condition of building

The age and existing condition of a building are factors to consider in assessing the tolerance to vibration. Older buildings may have soft mortar joints, simple footings or poor cross -bracing. Arches may be effectively articulated off the main structure. Modern buildings have limitations on deflections, deviations, inclinations, curvatures or widths of cracks allowed at the design stage. guidance is available with respect to cracking for modern buildings according to the building material involved whether the cracks are surface cracks or through- cracks, whether they are likely to open further or close, whether they are repairable or capable of being covered by decoration, whether water penetration is a factor and the probable attitude of persons affected, in view of the intended use of the building.

2.6.2 Building damages due to soil compaction

Depending upon the type of ground, ground vibration can cause consolidation or densification of the soil, which has been known to result in differential settlement and consequent building damage. Loose or especially water- saturated cohesion less soil is vulnerable to vibration which may cause liquefaction. It has been shown in laboratory tests that there can be a rearrangement of constituent particles at strains of 0.0001 and this becomes marked at strains of 0.001. Such soils, which may have shear wave propagation velocities of around 100 m/s start to become vulnerable at peak particle velocity values of about 10 mm/s. The damage to the soil structure is then a function of the number of cycles of straining. The loading transmitted to the soil though the foundation may reduce the vulnerability of the soil to such damage, but there are cases where the acceptable vibration limit may be set by consideration of soil-structure interaction, rather than distortion or inertial response of the building itself.

CHAPTER THREE

3 METHODOLOGY

3.1 Study area

The selected area is the villages along with the expressway trace from Kurudugahahetekma to Matara which is covered 30km. Nine divisional secretarial divisions have been taken to the data collection including Elpitiya, Karandeniya, Baddegama, Bope-Poddala, Akmeemana, Habaraduwa, Welipitiya, Malimbada, and Matara. High level of rural population live in this area is engaged in self employment and agriculture mainly paddy and tea.

3.2 Sampling procedure

Data was collected from the houses which were located within 50m from the expressway trace. Random sampling was adopted to collect necessary data.1547 houses were randomly selected and inspected and gathered data through structured questionnaire survey.

3.3 Data collection

3.3.1 Primary data

Data was collected through survey research methods using a carefully designed questionnaire in order to collect the required data.

According to the objectives mainly considered the structural damages in houses due to compaction activities. Structural damage was identified by doing the crack survey in existing condition and compares it with respect to the post crack survey data which was taken after the compaction activities.

Data was collected along the highway trace from Kurudugahahetekma to Matara by covering all the compaction activities area. 1547 Houses are inspected and recorded the data.

3.3.2 Secondary data

In addition to survey data, structured interviews and discussions were carried out as and when necessary to get more in-depth information.

Secondary data including company records also used to clarify certain issues.

3.4 Data analysis

Collected data were analyses by using Microsoft Excel and SPSS software.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

According to the objectives of the study mainly considered the structural damages in houses due to compaction activities. These are the major findings of the study.

4.1 Types of houses

Houses were inspected from Kurudugahahetekma to Matara in nearby expressway trace. All the surveyed houses are categorized as below.

Table 4-1. Types of houses

Type of house category	No of Houses
Double store	93
Single store built with cement blocks	720
Single store built with standard bricks	558
Daub and wattle houses	115
House built with woods	81

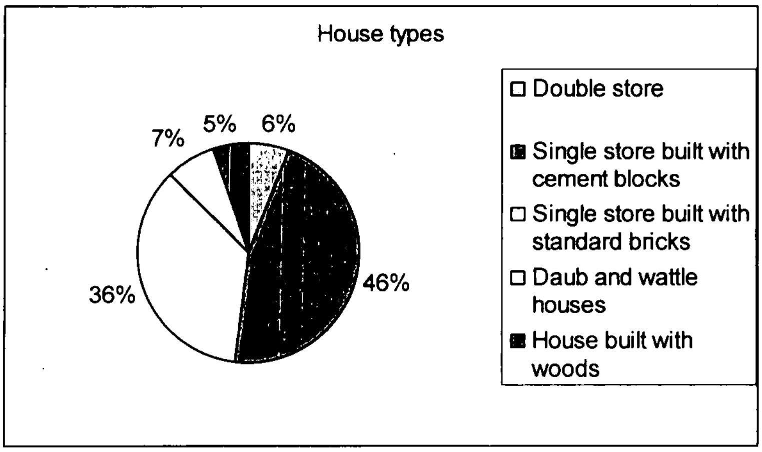


Figure 4-1. Types of houses

Majority of the houses were built with cement blocks and single store. It is 46%. Considerable number of houses was built with daub and wattle as well as wood.

People live in this area belongs to middle level and poor categories. Most of them are farmers.

4.2 Age of the houses

All the houses were categorized with respect to the age of the houses. Majority of the houses were built more than 10 years ago. Those houses can be seriously affected due to the ground vibration in compaction activates.

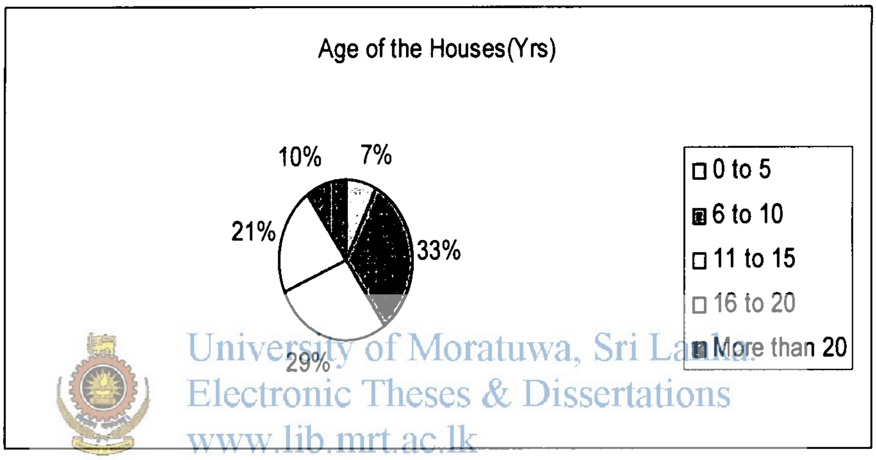


Figure 4-2. Age of the house

4.3 Structural damage assessment

Crack survey was done by every house near by the highway trace which has the possibility of affecting the houses in compaction activities. Cracks were marked and recorded using a combination of visual inspection and photography. In this method, all existing cracks were recorded. When compaction activities are proceeding, these records should be regularly reviewed. The inspection procedure of a particular structure is divided into two i.e. exterior inspection and interior inspection. During exterior inspection, floor, frames, painted or masonry construction, type of roof, gutters were noted while interior inspection, room by room with each room designated and described.

Ground vibration is playing the major role in this scenario. Normally when the ground vibration readings in particular house exceeds more than 2 mm/s it is considered as affected house (according to the Central environment authority regulations). Residences in that affected house is not allow to live in the house when the compaction activities going on. Therefore residences are temporary evacuated for particular period by paying evacuation payment.

When the compaction activities were finished, post crack survey was done to identity the present situation of the house. After that both existing and post crack survey results are analyzed to identify the real damage of the house due to compaction activities. Clint and the contractor of the highway project were agreed to repair the damaged houses before starts the project. After that every affected house is estimated by an independent party using the crack survey results.

There are 3 types of cracks identified. They are;

- Minor cracks
- Intermediate cracks
- Major cracks

Each type of crack is divided in to ten sub divisions.

4.3.1 Minor cracks

Crack width in below 1 mm.

Table 4-2. Standard Categorization of minor cracks

Type	Length (mm)
A	0-19
B	20-39
C	40-59
D	60-79
E	80-99
F	100-119
G	120-139
H	140-159
I	160-179
J	180-199

Minor cracks are categorized into 10 groups according to the length and the width of the crack.

4.3.2 Intermediate cracks

Crack width is between 1mm -2 mm.

Table 4-3. Standard Categorization of intermediate cracks

Type	Length (mm)
A	0-19
B	20-39
C	40-59
D	60-79
E	80-99
F	100-119
G	120-139
H	140-159
I	160-179
J	180-199

4.3.3 Major cracks

Crack width more than 2 mm

Table 4-4 *Standard Categorization of major cracks*

Type	Length (mm)
A	0-19
B	20-39
C	40-59
D	60-79
E	80-99
F	100-119
G	120-139
H	140-159
I	160-179
J	180-199

4.4 Crack survey data analysis

Crack survey data was analyzed as follows. Pre survey and post survey data were compared and crack increment percentage was identified. Considered the average number of the cracks of 1547 houses and summarized as below.

Table 4-5 Pre –crack survey data analysis

Pre Survey								
Minor Cracks			Intermediate Cracks			Major Cracks		
Type	Average	%	Type	Average	%	Type	Average	%
A	6	31.6	A	0	0.0	A	0	-
B	5	26.3	B	5	31.3	B	2	-
C	2	10.5	C	1	6.3	C	0	-
D	2	10.5	D	3	18.8	D	0	-
E	2	10.5	E	2	12.5	E	1	-
F	2	10.5	F	2	12.5	F	1	-
G	0	0.0	G	1	6.3	G	0	-
H	0	0.0	H	0	0.0	H	0	-
I	0	0.0	I	0	0.0	I	0	-
J	0	0.0	J	2	12.5	J	1	-

Minor	19	47.5	Inter	16	40.0	Major	5	-
Total Cracks		40						

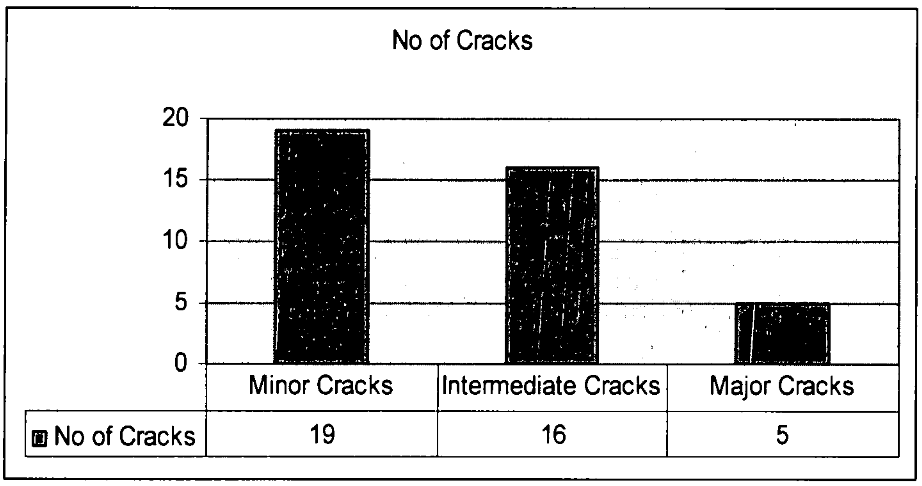


Figure 4.3: Pre crack survey

According to the results minor, intermediate and major cracks had reported in the pre crack survey. Nearly 12.5% of the major cracks, 40% of the cracks are intermediate cracks and 47% found as minor cracks.

Table 4-6 Post- crack survey data analysis

Post Survey								
Minor Cracks			Intermediate Cracks			Major Cracks		
Type	Total	%	Type	Total	%	Type	Total	%
A	7	33.3	A	1	5.9	A	0	0.0
B	7	33.3	B	4	23.5	B	3	33.3
C	2	9.5	C	2	11.8	C	0	0.0
D	2	9.5	D	3	17.6	D	0	0.0
E	1	4.8	E	3	17.6	E	2	22.2
F	1	4.8	F	2	11.8	F	2	22.2
G	0	0.0	G	1	5.9	G	1	11.1
H	0	0.0	H	0	0.0	H	0	0.0
I	0	0.0	I	0	0.0	I	0	0.0
J	1	4.8	J	1	5.9	J	1	11.1

Minor	21	44.7	Inter	17	36.2	Major	9	19.1

Total Cracks	47

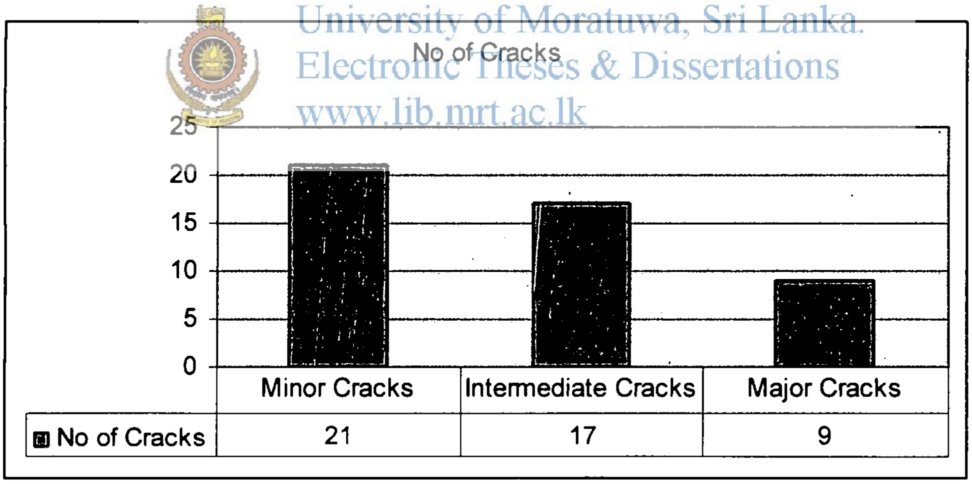


Figure 4-3 Post crack survey

In post crack survey some minor cracks in pre survey is developed as an intermediate or major cracks. It is reported that there are 44.7% minor cracks, 36.2% intermediate cracks and 19.1% major cracks.

Figure 4-4 Comparison of Pre survey-Post survey

Pre Survey-Post Survey Comparison											
Minor Cracks				Intermediate Cracks				Major Cracks			
Type	Pre C/S	Post C/S	%	Type	Pre C/S	Post C/S	%	Type	Pre C/S	Post C/S	%
A	6	7	5.3	A	0	1	6.3	A	0	0	0.0
B	5	7	10.5	B	5	4	-6.3	B	2	3	20.0
C	2	2	0.0	C	1	2	6.3	C	0	0	0.0
D	2	2	0.0	D	3	3	0.0	D	0	0	0.0
E	2	1	-5.3	E	2	3	6.3	E	1	2	20.0
F	2	1	-5.3	F	2	2	0.0	F	1	2	20.0
G	0	0	0.0	G	1	1	0.0	G	0	1	20.0
H	0	0	0.0	H	0	0	0.0	H	0	0	0.0
I	0	0	0.0	I	0	0	0.0	I	0	0	0.0
J	0	1	5.3	J	2	1	-6.3	J	1	1	0.0
Minor	19	21	10.5	Inter	16	17	6.3	Major	5	9	80.0

Total Cracks on Pre Compaction C/S	40
Total Cracks on Post Compaction C/S	47
Crack Increment Percentage	17.5 %

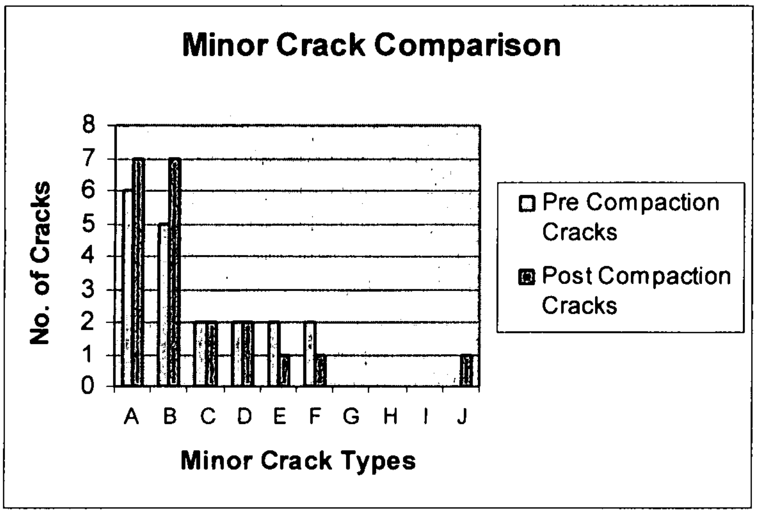


Figure 4-5 Minor crack comparison

According to the chart above number of post compaction cracks are higher than the number of pre compaction cracks.

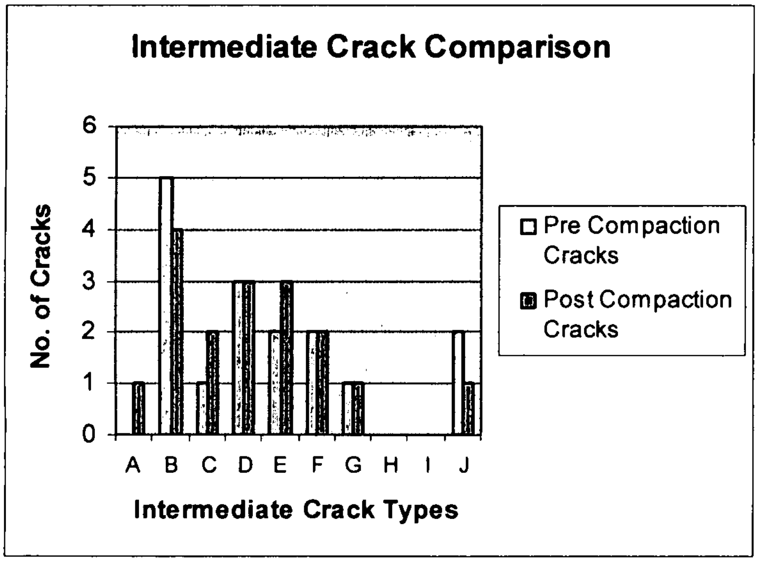


Figure 4-6 Intermediate crack comparison

Above figure shows the difference between pre crack survey and the post crack survey according to the intermediate crack categories.

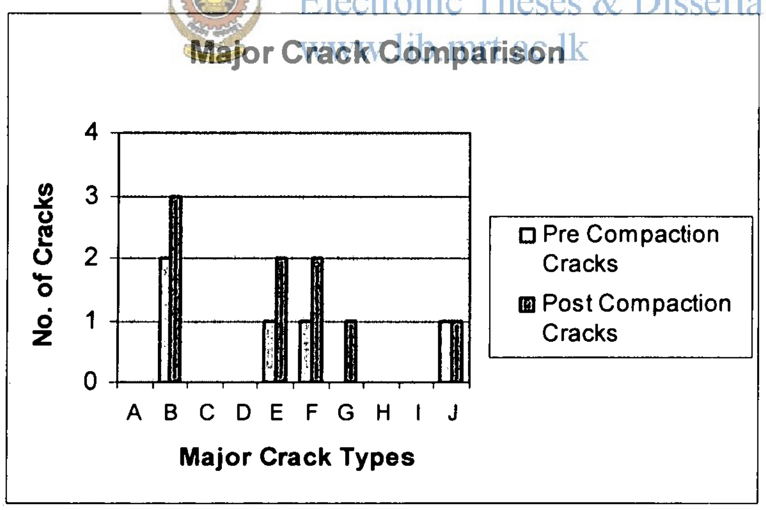


Figure 4-7 Major crack comparison

According to the above figure number of major cracks in the post crack survey is higher than the number of major cracks reported in the pre crack survey.

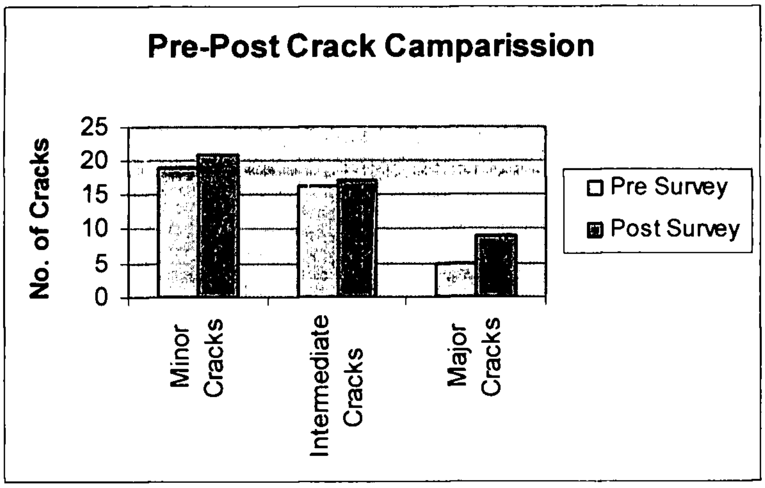


Figure 4-8 Pre post crack comparison

When comparing the pre and post crack surveys in all three kinds of cracks (minor, intermediate, and major) are higher in the post crack survey than the pre crack survey.

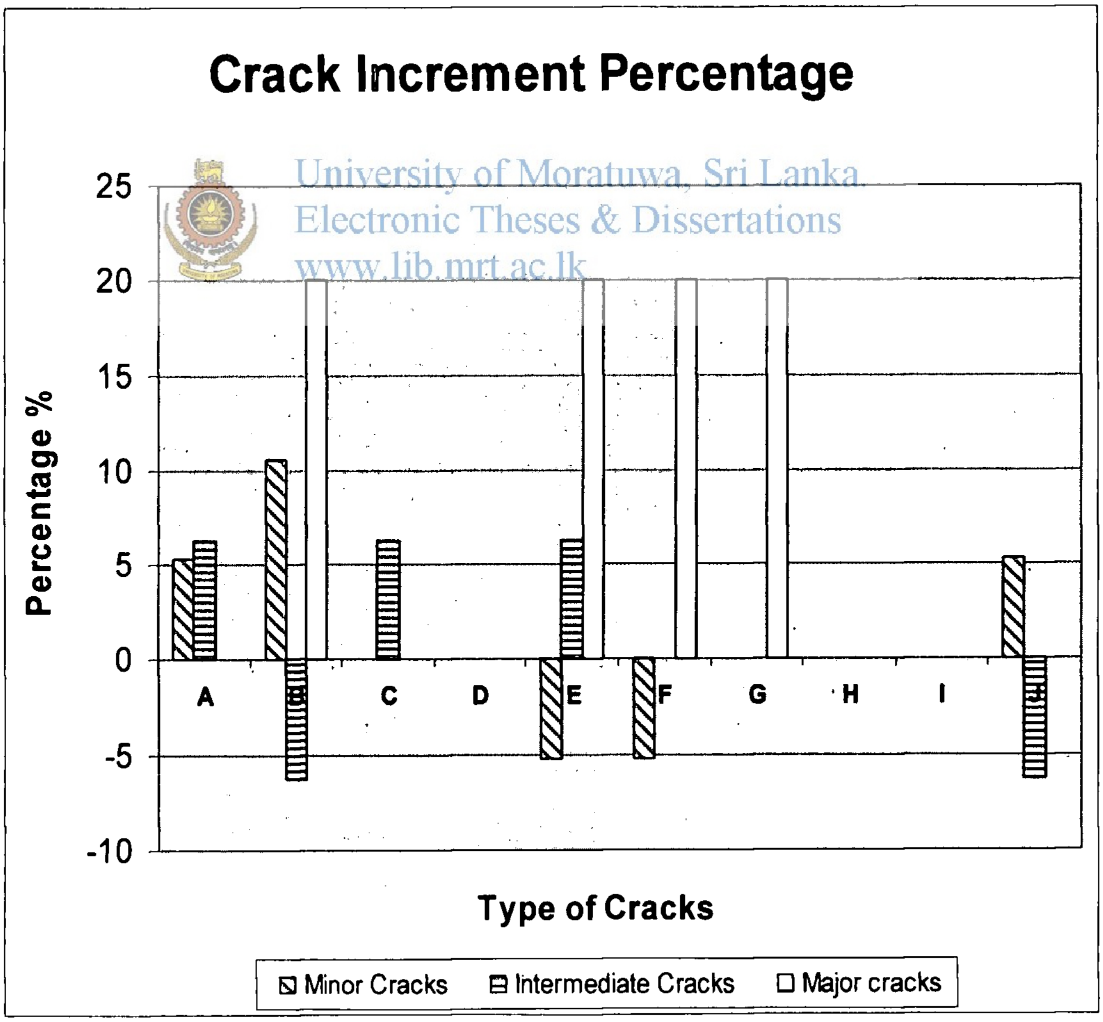


Figure 4-9 Crack increment percentage

4.4.1 Crack increment percentage for all the houses

All the houses were summarized with respect to the crack survey increment percentage. More than 75% of the houses were damaged in 20% due to compaction activities in near by the highway trace.

Table 4-7 Crack increment percentage

Crack increment percentages %	No of houses
No crack increment	38
0-10 %	481
10.1 – 15%	397
15.1- 20%	261
20.1- 25%	96
25.1-30%	109
30.1-35%	42
35.1-40%	49
40.1 -45%	31
45.1 -50%	20
More than 50%	23

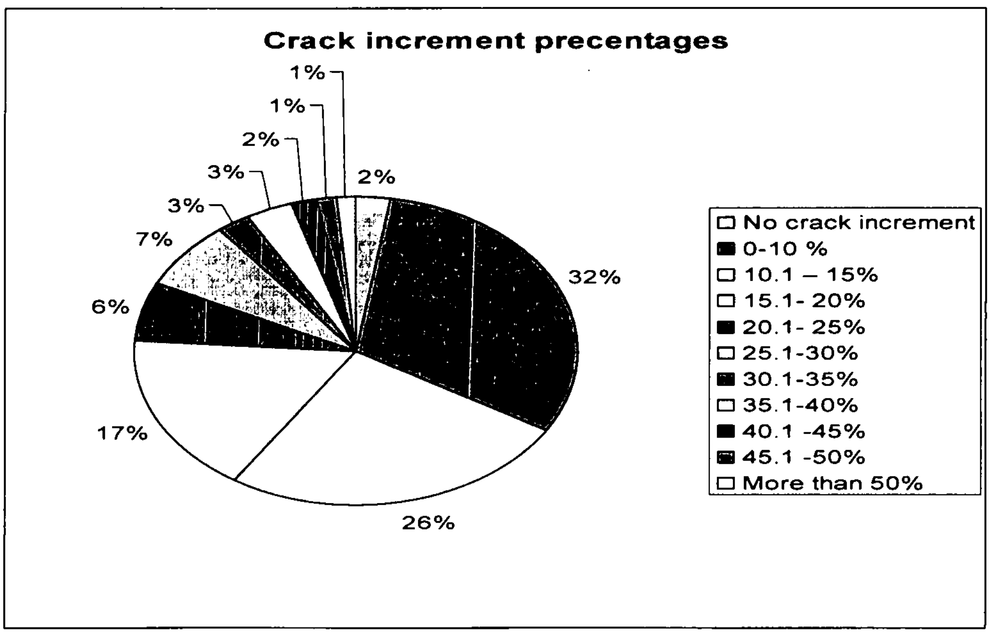
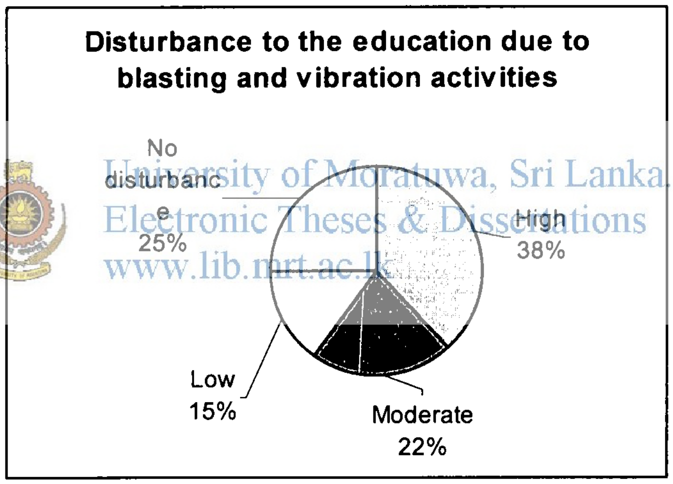


Table 4-8 Crack increment percentage

4.5 Impact to the people due to compaction operations

Compaction activities are generated significant amount of disturbance to the people who are living near the highway trace. Some time people are trying to stop the construction works due to inconvenience of the compaction operations. Generally it generates little bit conflict with contractor and the residences. People who are affected due to excessive vibrations are temporary evacuated from the house for particular time period. They have paid by the contractor in 8,333.33 rupees per month. Geological survey & Mines bureau is doing the compaction monitoring and given some recommendations to the contractor for evacuation the people.

4.5.1 Responses from the school children:



Children who are schooling also interviewed during the questionnaire survey to identify the impacts for their education due to blasting and vibration activities. According to their responses 75% of students mentioned that they can't concentrate their minds to the education due to high sound of blasting and vibrations due to compaction. Twenty five percent of students mentioned that there is no any impact of these construction activities for their studies.

4.6 Limitations

The research will done in selected environment related institutions and public which are involving this purpose & therefore the answers & discussion may be biased and these finding may be not be generalized to any other construction projects in Sri Lanka

It is noticed that all the measurements and photographs were taken from visible cracks to the naked eye. But there may be micro cracks and old cracks, which have been re-plastered.

The measured lengths and thickness of cracks were valid for the date of observation. Therefore, the propagation of the cracks should be monitored periodically. The measured lengths can be varied as ($x \pm 10$ mm) due to occurring of human errors.

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

After analyzing all the data we can clearly identify that there is a clear affect on houses due to vibration in construction activities. Majority of houses have the limit of less than 25% of the crack increment percentage due to the vibrations. Most of the affected houses are located less than 50 m from the highway trace. When we consider the blasting activities the affected range may go up to 200 m because of the high vibration generated by the powerful explosives which are used for blasting

Most of the houses in the project area were built more than 10 years ago. So those houses are not designed for excessive vibration parameters. These fore the damage because of the vibrations are high more than newly built houses. Sometimes we can clearly observed it when the comparing of crack propagation between the older house and the modern house. Earth slip may be another result from excessive vibrations. We have identified some areas can be slipped because of the too much vibration generated by the construction activities.

Environmental Impact Analysis (EIA) was not identified some issues related with the ground vibration in designed stage. According to the EIA, ground vibration due to compaction is minimized by increasing the number of roller passes with low vibration in particular construction area. In practical purpose it can't be used at the site in most of the time due to several reasons.

- Adverse weather condition - have to accelerate the soil Compaction due to rain
- High volume of compaction - compacted soil heights may be More than 20 m from the ground
- Running out of the time - some areas are more critical for compaction. So have to use high vibrations.

After the considering all the date which we collected during this period is more practical than the EIA predictions. EIA does not make much attention regarding the damages due to ground vibrations in nearly by houses. Actually EIA is not allowed to evacuate the people in nearby houses due to excessive ground vibration. For the practical reasons Road Development Authority (RDA) has made a decision to evacuate people by their expense. Evacuation free was paid by RDA to the affected people though the contractor. That was a major component of the project expenses. RDA was paid more than 500 million to the main contractor (KUMAGAI GUMI CO.LTD) from kurudugahahetekma to Pinnaduwa project trace.

In planning stage Southern highway project was proposed to finish with in 5 years. Due to some reasons finish of the project is delayed almost 3 years especially in project loans and adverse weather conditions. We can identify the few short comings in planning stage in this project.

- Didn't make sufficient attention regarding the ground vibrations
- Drainage pattern of the area was not considered much.
- Socio economic factors of the area.
- Introduce unrealistic designs to the project(especially the metal arch concept)
- Road access to nearby residences

Central Environment Authority (CEA) and Geological Survey & Mines Bureau (GSMB) are playing very vital role in this project. All the permits should take from these government institutes under rules and regulations of srilanka. Blasting parameters were designed after the test blast conducting in relevant location by CEA and GSMB. Other than the government institutes there are well experience geo technical experts and environmental engineers working with the project for the project success. Monthly meeting were arranged to discuss relevant issues regarding environments with experts.

Southern highway project was the first highway project in srilanka. So we can identify much more short comings during the project. By considering the situation in Srilanka more expressway projects will implement in future. Therefore southern expressway should be a guild line for those future projects in srilanka. Finally we can do following suggestions for success of coming projects.

- Implement of the EIA project proposal process with the help of vast range of experts and relevant villages
- Evacuation should be done with the project trace over looking with future development
- Ground vibration can be minimized with the help of technology and introduce new construction techniques
- People around the project area should be educated regarding the importance of the project to minimize the project delays
- Try to implement new techniques that relevant to srilanka
- Road Development Authority (RDA) should be carefully monitored about the project progress

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Appendix 1

Sample of data collection questioner

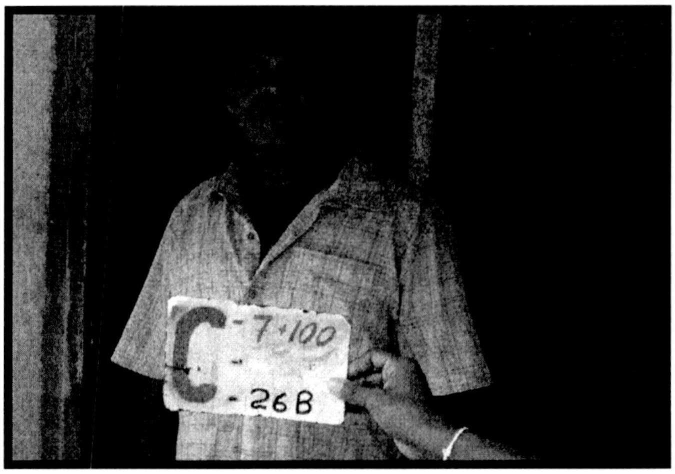
(1) Identification number of house:		
(2) Photo notation:		
(3) Approximate age of the house:		
(4) Details of the land in which house was built on:		
(5) Existing structural detail		
5.1 Detail of the roof:		
5.2 Detail of the walls:	**5.2.1 Material type:**	
	5.2.2 Thickness :	
5.3 Detail of the plaster:		
5.4 Detail of the windows:		
5.5 Details of floor		
5.6 Details of foundation		

Sample of crack survey report;

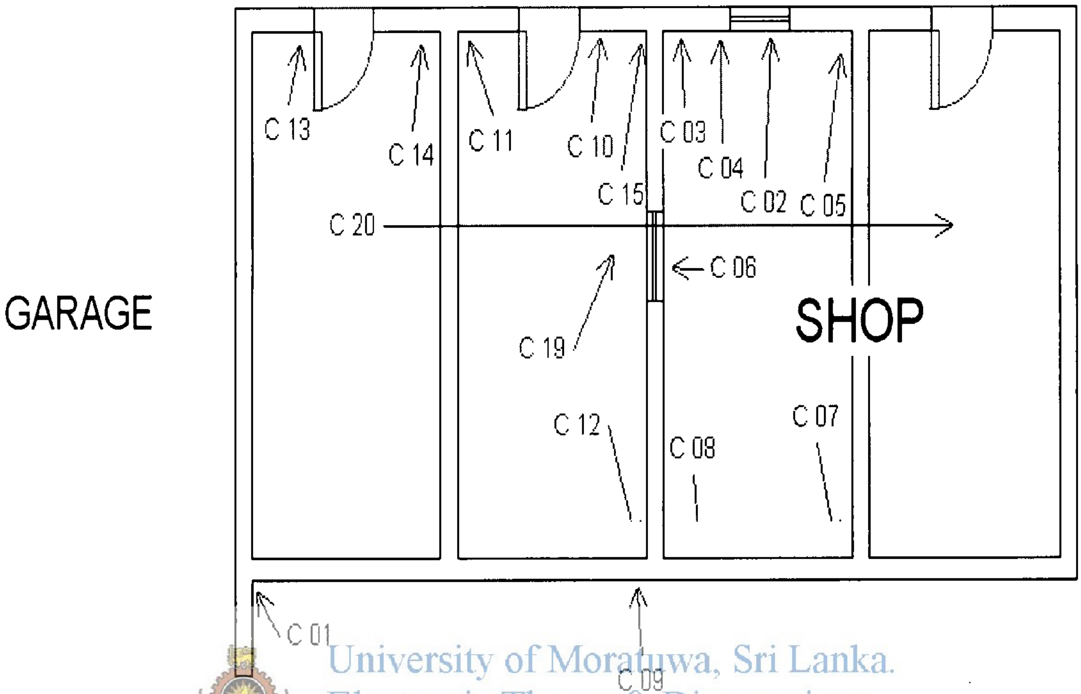
Location: 07+100 Km
House No: C 26 B (Shop)
Name : G.W.Mahindalal

1.1.1.1.1.1 Address :
Paranajanapadaya,
Ethkandura.

GPS Coordinate:
E – 132212
N – 115636



(1) Identification number of house:	C-26 B	
(2) Photo notation:	NC^{07+100} 26B - 01 - NC^{07+100} 26B - 03	
(3) Approximate age of the house:	18 Years	
(4) Details of the land in which house was built on:	Existing ground	
(5) Existing structural detail		
5.1 Detail of the roof:	Roof tile standard	
5.2 Detail of the walls:	**5.2.1 Material type:**	Standard brick
	5.2.2 Thickness :	200 mm
5.3 Detail of the plaster:	Both sides were plastered	
5.4 Detail of the windows:	Wooden	
5.5 Details of floor	Cemented	
5.6 Details of foundation	Rubble & Masonry	



Plan view of the House

(6) Details of cracks at the Pre-Survey & Post Survey					
Crack No	**Pre-Survey**		**Post-Survey**		**Remarks (Orientation of Cracks)**
	Length cm	**Thickness mm**	**Length cm**	**Thickness mm**	
C 01	280	20	300	25	Separation between wall
C 02	96	02	102	04	Upward from bottom of the wall
C 03	60	02	70	03	Downward from bottom of the wall
C 04	163	02	180	03	Horizontally on above the left side of the window frame
C 05	73	02	75	03	Downward from top to bottom though the wall joint
C 06	68	02	70	03	Downward from below the window frame on both sides of the wall
C 07	70	02	80	03	Downward from top to bottom
C 08	32	02	45	03	Horizontally on above the right side of the door frame
C 09	96	02	102	03	Downward from top to bottom
C 10 i	155	02	160	03	Horizontally on top of the door frame
ii	55	02	60	03	Upward from above the right side of the door frame
C 11	110	02	120	03	Downward from top to bottom
C 12	280	02	300	03	Downward from top to bottom though the wall joint
C 13	50	02	60	03	Upward from above the left side of the door frame
C 14	43	02	50	03	Downward from top to bottom

C- Crack **MC** – Minor crack
NC- New Crack **NMC** – New Minor crack

(7) Details of cracks formed after Pre-Survey			
Crack No	**Length cm**	**Thickness mm**	**Remarks (Orientation of Cracks)**
G	65	2	Damage on the garage
F	32	4	Crack on the cement floor
P	98	3	Crack on the pavement
Note			Slightly displacement of the roof