ASSESSMENT OF STRUCTURAL VULNERABILITY OF SRI LANKAN HOSPITALS UNDER NATURAL HAZARDS – TSUNAMI AS A CASE STUDY

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Degree of Master of Philosophy

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Thesis submitted in partial fulfillment of the requirement for the degree Master of Philosophy in Civil Engineering

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DECLARATION

I declare that this is my own research thesis and this thesis does not incorporate without acknowledging any material previously published submitted for a Degree or Diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

Signature: Date:

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15.09.2021

H.H.H. Hasalanka

I have read the thesis and it is in accordance with the approved university proposal outline. I am willing to supervise the research work of the above candidate in the proposed area.

Signature of the Supervisor(s): Date:

UOM Verified Signature

16-09-2021

Dr. C.S.A. Siriwardana

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16-09-2021

Dr. H.M.Y̆.C. Mallikarachchi

ABSTRACT

Hospitals are considered critical service units of a society that need to operate before, during, and after disasters. The Ministry of Health of Sri Lanka has embraced the "Safe Hospitals" Initiative promoted by the World Health Organization (WHO), as a strategic priority for health sector Disaster Management to strengthen the resilience of the hospitals. WHO has developed a toolkit for the assessment of the safety of hospitals including structural, non-structural, and functional aspects. This toolkit consists of four modules that are; hazard identification, structural safety, non – structural safety, and emergency and disaster management. A review of this toolkit has pointed out the need for major alterations to the structural safety module of the Safe Hospital Toolkit to Sri Lanka since the Sri Lankan disaster profile is quite different from that of the Latin American countries in which the toolkit was developed; where earthquakes and cyclones are predominate. The objective of this assessment was to develop a toolkit to assess the structural safety of hospitals in Sri Lanka addressing the structural vulnerability/robustness of buildings considering natural hazards; high winds, floods, tsunamis, and landslides. Accordingly, a draft Structural Safety of Hospitals assessment Sri Lanka (draft SSH – SL) has been developed based on the Safe Hospital Toolkit and the available Sri Lankan guidelines for hazard resilient constructions. Then, the draft SSH – SL has been used in a pilot study to identify its limitations, on two hospitals based on their functionality, namely the District General Hospital Gampaha and the Teaching Hospital, Kegalle. To further develop the SSH - SL, field data of another pilot study conducted on six hospitals on the southern coast are used along with a thorough literature review. Moreover, expert surveys were conducted to further improve the toolkit and to obtain the weights using the Analytical Hierarchy Process (AHP), for all the criteria in the SSH – SL, and a Structural Robustness Index (SRI) is defined. Finally, the developed tool under tsunamis is checked for applicability based on the data obtained from the second pilot study and is validated by comparing the actual damage occurred in 2004 Indian Ocean Tsunami with the obtained SRI scores. However, the developed tool for other assessments require validation through more case studies. According to the relative weights obtained through AHP, two main attributes; construction material and the foundation system

were found to be significantly important. The assessments of tsunamis and floods share the same building attributes with different weights; the attributes of the lateral load resisting system and the number of stories get a higher weight under the tsunamis compared to floods, as the impact loads applied by the tsunamis are higher than that of the floods. Considering the SRI scores, it was found that the median score for the general assessment is 3 whereas it is 2.33 for all the other assessments. This gives a clear idea of the robustness of buildings as the SRIs above the median score are tend to be robust and the SRIs below the median tend to be vulnerable. The case study carried out focussing on the assessment developed for tsunamis suggests that the Structural Robustness Index (SRI) method is a more nuanced and improved method for assessing the structural robustness compared to the PTVA method. It is highlighted that the SRI method identifies structures that are above the median level in terms of structural robustness than that of the PTVA method. As far as the intra-hospital variation is concerned, the SRI variation mostly depends on the building attributes such as the number of storeys and the construction material. It is also identified that there is a coupling effect between building attributes such as the construction material and the number of storeys as the buildings with a higher number of storeys are also tend to be made of reinforced concrete frames whereas the single storey buildings are made of masonry. The inter-hospital variation of SRIs mostly depends on the surrounding attributes as they change with the geographical location. These results are valid for the buildings up to four storeys including unreinforced masonry, reinforced concrete structures with masonry infills, and reinforced concrete framed structures that were assessed during the field survey. The SSH - SL could be further improved by incorporating the level of exposure and functional attributes and emergency and disaster management attributes to develop a comprehensive risk index, which is beneficial for the disaster management decision-making stage of hospitals.

Key Words: Safe Hospitals; Hospitals; Hazards; Structural Vulnerability; Structural Robustness; Safe Hospitals Toolkit; Hazard Resilience; Analytical Hierarchy Process (AHP)

ACKNOWLEDGMENTS

I would like to express my sincere gratitude towards my research supervisors Dr. C.S.A. Siriwardana and Dr. H.M.Y.C. Mallikarachchi for their guidance provided throughout this research study duration and for assisting in getting access to hospitals for surveys. The encouragement and the commitment provided were very important in achieving the objectives of the research study. Further, the SRC long-term grant (2018) council memo 446/06/09 is also acknowledged for providing funding for twenty months (April, 2018 to January, 2020).

I would like to express my gratitude, especially to Prof. W.P.S. Dias, who is the panel chair of progress reviews for proving extremely valuable comments and guidance throughout the research period to make the research study this successful.
I would like to express my appreciation to the former Research Coordinator of the Department of Civil Engineering University of Moratuwa, Prof. A.A.D.A.J Perera for the valuable comments provided throughout the progress evaluation periods to make the research study more successful. Moreover, the current research coordinator Dr. J.C.P.H. Gamage is also acknowledged for being helpful in the process.

Further, this research work was undertaken with the support and guidance provided by the National Disaster Preparedness and Response Division (DPRD) of the Ministry of Health. The support provided by the DPRD officials; Dr. H.D.B. Herath, Dr. A. Wedamulla, Dr. N.W.A.N.Y. Wijesekara, and Dr. K.A.L.C. Kodituwakku were immensely helpful in getting access to the hospitals for the assessment and providing the required data for the study.

Moreover, I would like to deliver my sincere thanks to the team represented from University College London (UCL) for delivering the excellent support provided to the structural assessment of hospitals in the coastal belt in Sri Lanka. The HEART-SL project could be completed successfully with the support provided by the UCL team; Dr. Marco Baiguera, Dr. David Robinson, and Eng. Juan Polomino, as well as the support provided through the main guider in Sri Lanka, the team from UOM; Dr. Chandana Siriwardana, Eng. Devmini Kularatne, Eng. Ishani Shehara, Eng. S. Harisuthan, and Eng. Bahirathan Koneswaran.

Finally, I would like to thank all who supported me in conducting this research study and completing it at a successful level of achievement.

Thank You,

H.H.H. Hasalanka

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LIST OF ABBREVIATIONS

Abbreviation	Description
AHP	Analytical Hierarchy Process
BH	Base Hospital
CHC	Community Health Centres
DPRD	Disaster Preparedness and Response Division
GDP	Gross Domestic Product
DGH	District General Hospital
DH	District Hospital
DS	Divisional Secretariat
EDM	Emergency and Disaster Management
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
ICU	Intensive Care Units
MAUT	Multi Attribute Utility Theory
MCDM	Multi Criteria Decision Making
MOH	Ministry of Health
NICU	Neonatal Intensive Care Units
OPD	Out Patient Department
RSVIH	Relative Structural Vulnerability Index for Hospitals
RVA	Rapid Visual Assessment
WHO	World Health Organization
PAHO	Pan American Health Organization

PBU	Premature Baby Units
PHC	Primary Health Centres
PMCU	Primary Medical Care Units
PTVA	Papathoma Tsunami Vulnerability Assessment
RC	Reinforced Concrete
RSRIH	Relative Structural Robustness Index for Hospitals
RVI	Relative Vulnerability Index
RVS	Rapid Visual Screening
SSH-SL	Structural Safety of Hospitals in Sri Lanka
SRI	Structural Robustness Index
TH	Teaching Hospital
UCL	University College London