## Analysis of Seismic Waves In Highways

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**Abstract**

Seismic surface wave testing can give important information to material portrayal of pavement layer properties. Measurements can be preceded as quality control during or after construction of pavement. The stiffness & thickness of the top layer in a pavement construction can be assessed in a basic way dependent on Lamb wave propagation in a free plate. However, because of the complex interactions of higher methods of Lamb type of waves in the implanted layers the assessment of deeper pavement layers is more challenging. A strategy for full-wave field reversal is depicted and demonstrated on a genuine pavement construction. Ongoing advancements towards non-contact scanning seismic testing of pavements using microphones is like wise introduced.

**I. Introduction**

**Introduction-** Seismic waves are energy waves which travel from one part to another part inside the earth layer and cause earthquakes, volcanic eruption and magma eruption from earth inside. Sometimes man made explosion also cause earthquakes1. There are many other source which cause seismic waves generation of low aptitude. Seismologist study’s the study of seismic waves. Seismometer is the device used for measure seismic waves. The velocity depends of waves upon the medium of travelling also the density and it also changes from going down to earth crust and mantle, but decrease from going to depth to mantle core. The earthquakes results in the various production of seismic waves of various velocities and different movement time by which the scientist check the centre of earthquake. There are various types of seismic waves but main waves are body waves and surface waves.

**Body waves**

They travel through the earth inside and control the density and stiffness modulus. Modulus stiffness depends upon the temperature, composition and material phase. Further body waves classify in to primary and secondary waves. Primary waves are compressive waves and travel longitudinally. They also known as p-waves and pressure waves there intensity is high other than secondary waves. They are independent of medium and they are faster than s-waves. Secondary waves are also known as s-waves they travels transversely. They are differ in differ medium there velocity also varies with surface or medium.

**Surface waves**

They travel over the surface of earth so known as surface waves. They only travel over the surface they will get diminish after leaving the surface connection. The speed intensity of surface waves are somehow less than p waves and s waves. Further there are love waves which are horizontal polarised shear waves, Rayleigh waves which are rolled surface waves which roll over the surface. They are elastic in nature. Stoneley waves these are boundary waves that propagate along a solid fluid. They travel between boundaries of the layer after striking their velocity keeps on increasing.

Conventional design of pavements depends on imperial models, with trial and error as basis for the choices. With this methodology it is hard to optimize natural and financial assets in each undertaking. Subsequently, modern pavement design is moving towards mechanistic and explanatory models. An essential for utilizing these models is that material properties, for example, Young's modulus (E- modulus), can be estimated and approved in the field. Stiffness properties acquired from seismic velocities are low strain parameters that can be utilized in logical pavement structure design (Ekdahl et al., 2004; Gudmarsson et al., 2014).

Since the early examinations by Jones (1962) and Vidal (1964) seismic surface wave methods have been perceived as an enticing methodology for non-destructive evaluation (NDE) of pavements. The introduction of the Spectral Analysis of Surface Waves (SASW) technique (Hersey et al., 1982; Nazarene, 1984) has brought about a widespread utilization of the strategy (Goel and Amines, 2008). In this paper we portray an alternative procedure to the SASW technique, which contrasts in information obtaining, information handling, and assessment. The proposed approach depends on a theoretical investigation of guided waves in pavement systems (Ryden and Lowe, 2004). Information assortment and preparing depends on the Multichannel Analysis of Surface Waves (MASW) strategy (Park et al., 1999). The assessment of pavement layer properties can be separated into two different methods; one quick and straightforward technique for the stiff top layer and a second further developed full wave field reversal for all pavement layers.

**II. Literature Review**

1. **PACT**

PACT was developed by Federal Emergency Management Agency (FEMA) of United States of America. It is an electronic tool developed to estimate the probabilistic future loss due to earthquakes in the areas of human casualties, building repair or rebuilding costs, rebuild time, and probability unsafe placarding. This tool was developed based on the framework developed by Pacific Earthquake Engineering Research Center (PEER) on performance-based seismic engineering framework. It requires inputs like the ground shaking intensities, feedback from the building to the earthquakes vibrations, fragility functions that expresses the probability of certain damage (a damaged state) occurring in component due to each earthquake intensity, components that are in the building, required cost for repair the stated building, and number of occupant that resides in the building over time. The quantitative input of these requirements will generate the likely consequences of each damage state in terms of downtime, repair cost, casualties, and unsafe placarding. (Federal Emergency Management Agency, 2012c; Harris, Bonneville, Kersting, Lawson, & Morris, 2013).

1. **SLAT**

SLAT is also based on the PEER framework on probabilistic seismic loss estimation mentioned above. This tool was developed by the University of Canterbury in New Zealand. SLAT is used to estimate the expected downtime, repair cost and casualties using similar inputs. But, SLAT does not estimate the probability of unsafe placarding to occur. PACT had much more built-in fragility curves and consequence functions and was a basis for SLAT. SLAT is currently in its development stage and mainly focusing on earthquakes related to New Zealand (B. A. Bradley, 2009).

1. **High-level comparison between SLAT and PACT**

There is no exact literature comparing SLAT and PACT. In comparison, this two software have many common characteristics. These tools use PEER framework on performance based seismic loss estimation using probability. Both tools require similar input and output requirements such as ground shaking intensities, the reaction from the building to the earthquakes vibrations, component fragility functions, required cost of repair for the stated building, and occupancy over time. Based on the inputs they produce a cost for repairing damages, downtime of the building and casualties, which are produced by assigning different damage states in fragility curves for each component and assigning consequences to each damage state. Consequence functions use the same structure, using upper quantity, lower quantity, maximum cost, minimum cost and dispersion to express cost variations (B. A. Bradley, 2009; Federal Emergency Management Agency, 2012c).

The information collected for PACT is from USA and SLAT from New Zealand (B. A. Bradley, 2009; Federal Emergency Management Agency, 2012c). Therefore, fragility curves and consequence functions cannot be globally used. This is due to the fact that, behaviour of building components and its behaviour will depend on the standards and practices utilised for its construction. For repair cost, consequence functions factors like location, material costs, labour costs and other environmental factors will affect its figure in addition to regional standards and practices (Ashworth &Perera, 2015).

Though SLAT was developed based on PACT, there are some main differences that can be identified in the two systems. When considering the inbuilt data bases, PACT provides a larger number of built-in fragility curves and consequence function than SLAT. These inbuilt data of both software are specific to its region, PACT is suitable for United States region and SLAT is suitable for New Zealand region. In the software distribution point of view, PACT is provided in a downloadable ‘.exe’ format as well as spreadsheets of the inbuilt data. SLAT provides a web-based interface where users can input data and retrieve the output through server processed information. The inbuilt data in PACT is provided as spreadsheets, with clearly detailed user manuals enable the users to understand the processes and data used. On the other hand, SLAT has black box method in processing data through servers and the provided user manuals require additional knowledge to understand the processes thoroughly. Thus, PACT has more transparency than SLAT.

Both systems use classification systems to identify and categorised fragility curve according to the component types. PACT uses NISTIR 6389 standard classification system. This classification system is based on the UNIFORMAT II classification system. This system has six main categories and four sub levels. Currently, SLAT doesn’t use any standard classification system. It uses a unique classification system which has three main categories and one sub level (B. A. Bradley, 2009; Federal Emergency Management Agency, 2012c)..

When comparing the inbuilt population models, PACT provided models for ten different types of buildings depending on its usage. These include commercial offices, healthcare, hospitality, residential buildings. SLAT has no indication of such population models. On the other hand, loss assessment functions in PACT is limited to buildings were as SLAT has included functions for bridges as well. Inbuilt consequence functions of PACT are provided in detailed breakdowns and can be updated by the user, but, these functions in SLAT cannot be updated by the user and input data on cost is limited to cost of demolition and collapse by the web interface.

1. **Limitations and drawbacks of SLAT and PACT**

Some limitations of these systems and their inbuilt fragility curves and consequence functions are expressed in the guides and user manuals of the tools. Some of these limitations expressed apply to both tools. Furthermore, Redi framework has also expressed some limitations. (Almufti et al., 2013; B. A. Bradley, 2009; B. Bradley et al., 2017; Federal Emergency Management Agency, 2012a, 2012b, 2012c)

One drawback of these systems is that they do not factor in sudden cost increases due to high demand (B. A. Bradley, 2009). Major hazards cause damages to larger region instantly. Due to these damages, a sudden need for construction materials, labour and professionals can be seen during the post-earthquake recovery stage. This rapid increase in demand cannot be catered by the standard supply of construction industry. Which will cause a rapid and unexpected increase in construction cost. The construction cost increase of 40% and 20% after 2010-2011 Christchurch earthquake and 1992 Hurricane Andrew are few examples (Almufti et al., 2013). This sudden increase in cost of construction is referred to as loss amplification. Not accommodating this phenomenon will vary the estimates indefinitely.

The tools limited to component downtime rather than targeting the whole building. There are many factors affecting downtime other than separate downtime of each component. First, impeding factors, which the time delay from the event of the earthquake to start of repair, like time to complete building inspection, mobilisation of contractors, ordering and receiving components that required a substantial amount of time to be delivered. Secondly, repair sequence, which directly affects the total time required to repair. These items are not considered in the tools. (Almufti et al., 2013)

These software does not consider the effects of aftershocks. Major earthquakes are accompanied by a series of small shocks which are known as aftershocks (USGS Earthquake Hazards Program, 2017a). These aftershocks can damage the buildings further. Thereof effects of aftershock should also be considered (Jordan, Lander, & Black, 1965). When accompanying the effects of aftershock to a model, current damaged state of the building should be considered. But this damaged states and effects of aftershocks are not considered by PACT or SLAT. They only consider the building at its original state and does not consider the effects of aftershocks (B. A. Bradley, 2009). But, FEMA, (Federal Emergency Management Agency, 2012c) has expressed that an additional damage state for residual drift ratio has been added to accompany the effects of aftershocks in PACT tool.

These tools only generate estimates for full recovery of buildings, but there are stages of recovery for building in the event of an earthquake. Almufti et al. (2013) describe three of such recovery stages. Re-occupancy, when the building is used only for shelter, functional recovery, when the building can be used for the specified primary use, and full recovery, when the building is repaired to its original pre-earth state. Different stakeholders like building occupants, building owners and government officials, require the repair cost required to attain these stages. This because some buildings might not be fully repaired and might only be partially repaired. These two tools are not equipped to estimate repair cost need to gain the Re-occupancy and functional recovery stages. This can be expressed as a limitation of the tools.

There are many dynamic factors affecting the cost of construction. These include the size of the project, locations, fluctuations, labour costs, material cost, market conditions, overheads and profits (Ashworth &Perera, 2015). Due to the interrelation during component repair, cost per component should include a global cost component like preliminaries. These factors are lacking in these models. Ashworth and Perera (2015), further express that, to keep the models accurate, cost feedback is important. The system must be developed so the cost functions can be updated.

**III. Objective**

The fundamental anti- symmetric mode of vibration is the dominating mode produced in the stiff top layer. This mode drives the complete system and continuity across the limits producing higher order modes in the embedded second layer. The connection of leaky Lamb waves in the first and second layer results in huge variations in the excitability and the constriction, so only the waves corresponding to specific parts of the dispersion curves are measurable at the pavement surface. The analysis of seismic waves are yet to be find, they are calculated by various table calculation and derivation which are need to be analysed by so to complete analyse of waves a more research to be done briefly based on the properties .The top layer thickness, and stiffness properties can be acquired automatically in the field by a Lamb wave analysis of the measured phase velocity spectrum. Nonetheless, the reversal of deeper embedded layers depends on a more computationally demanding reversal of the full-wave field spectrum. Non-contact estimations utilizing ordinary audio microphones as receivers have demonstrated promising outcomes for quicker and more economically pavement testing in the future.

**IV. References**

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