UNIVERSITI TEKNOLOGI PETRONAS

Dynamic Response of Mrr2 Bridge at Ampang

by

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Dissertation submitted in partial fulfillment of
the requirement for the
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CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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Approved by,

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(Ap. Ir. Dr. Shahir Liew)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May, 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NUR AZRIN BINTI ISMAIL

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ABSTRACT

The goal of the bridge engineer is to design economical structures which are safe, durable and serviceable. Determination of the dynamic response of bridges has been the topic of numerous studies in recent years. Much of attention had been focused on maximum dynamic displacements and moments and on the distribution loads to the floor system which are the information necessary to design for adequate strength. Although humans are subjected to the vibrations of many structures, there is seldom any direct provision in design codes to ensure user comfort and usually impose restrictions upon girder depth-span ratios and upon static deflection-span ratios in the hope that these limits will provide satisfactory dynamic response. Another important concern, the comfort of those crossing the bridges, has received relatively little attention. Transportation agencies do receive occasional comments and complaints from bridge maintenance works, pedestrians and passenger in halted vehicles concerning the vibration of bridges. So, this study is conducted in order to identify the parameters that most affect the vibration of the bridge and to check the response of the MRR2 bridge that had experience a dynamic response whether it is safe or not.

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

Bridge is a structure that gives access to people and moving vehicles to places which beforehand were not available to in the first place. In designing bridge, there are certain parameters that need to be considering like dynamic load allowance, wheel load distribution factor, durability, fatigue, deflection control and so on. When the extreme ordinary vibration occurs on the structure, people usually might relate with the failure or collapse. The structure will be considered as durable when its function is acceptable in the actual environment. Durability is the capability in maintaining the serviceability of a structure over a specified time. Besides, it also needs to maintain its characteristics of the structure to function for a certain period with required safety and corresponding characteristics, which provide serviceability. When the structures exceed their durability limit, they will be considering as failure or collapse. For the structure reliability, it can be defined as the probability of a structure to fulfill the given function in its service lifetime which also means to keep the characteristics in given limits. In order to know either the structure performance is safe or not, the investigation needs to be done to the structure in order to check for the serviceability of the structure. Generally the most important serviceability limit states are deflection, cracking, durability, excessive vibration, fatigue, fire resistance and special circumstances. A structure that fails serviceability usually has exceeded a defined limit for one of the following properties which are excessive deflection, vibration and local deformation.

Besides, when it comes to structure design, there will be concern for comfort of users. Human reactions to vibration are both physiological and psychological (John. T Gaunt, 1981). Low frequency, large amplitude vibrations for example are associated with sea sickness on the other hand, when a person feels the traffic-induced vibration of a bridge, his reaction may be primarily psychological.
The analysis on dynamic response is important to check whether the bridge response can be accepted by the users and still durable even exceed the serviceability.

Besides, it is to gain the human confident on a vibration if the vibration is quite normal and not will be a failure.

1.2 Problem Statement

Several anxious users had been claimed a Kuala Lumpur Middle Ring Road 2 or MRR2 “swayed” during heavy traffic. MRR2 is a ring road build by the Malaysian Public Works Department (JKR) to connect neighborhoods near the boundary of Federal Territory of Kuala Lumpur and Selangor. The users alleged that the situation on the 35 km expressway as extraordinary because it could be clearly felt on the viaducts in Kepong and the Flamingo Hotel junction in Ampang, during heavy traffic. Prior to this, the Kepong viaduct was closed three times from 2004 when Kepong residents revealed that 7,000 cracks were found on 31 of the 33 pillars of the viaduct. On August 3, 2008, the viaduct was closed for the third time when cracks were discovered at the 28th pillar forcing the government to allocate RM70 million to repair the viaduct, which can accommodate 5,000 vehicles at one time. Respond for this claimed, the president for Board of Engineers Malaysia said that the vibration is still safe since the design of all bridges in Malaysia according to the British standard-BS5400.

Now, the problem is to know if the bridge is safe enough with that vibration. To solve this problem, the JKR had come out with alternative to do “A Comprehensive Study on the Vibration of Highway Bridges” in order to get a better understanding of the dynamic performance of highway bridges and the vibrations sensed by bridge users in order to establish the acceptable level of comfort and compliance with Code of Practice.

1.3 Objective

The main objective of this project is to study the reliability of the vibration from the bridge in order to check the serviceability of the bridge and gain the human confident on the vibration. Also, in other to achieve this, the study of acceptable level of human comfort will be conduct.

1.4 Scope of Study

Scope of works consists of a few parts which are:

i. Research on the design parameters of bridge to know the parameters that been considered related to dynamic loading on highway bridges.
ii. Study on human perceptions through the vibration to know the limitation of acceptance of vibration.

CHAPTER 2: THEORY

When considering the identification of damage in large structures, it is necessary to be very precise about what constitute damage. It is necessary to preview the mechanism that may cause collapse which the stage before such collapse occurs involve the loss of stability of an entire structure. Such indicators would include cracking, material degradation, fatigue and loss of continuity which one of these items may play a part in the reduction of usable life of the structure.

Before further view, the understanding on the concepts of elasticity, plasticity and the structural design guidelines that were in place when the bridge was built need to be clear first. The simple demonstration involving the bending of a partially uncoiled metallic paper clip can be use which illustrates the difference between elastic and plastic behaviors (Roberto.B, Taichiro O.). As the coiled portion of the clip is held tight and pushing the far end of the straight portion will produces a deformation that is associated with a rotation about the hinge point labeled H.

Figure 1: Uncoiled metallic paper clip

When a relatively small displacement is applied and then removed, the straight portion of the clip springs back to its original position. However if the applied displacement is larger than a critical amount, then the straight portion does not return to its original configuration upon removal of the force. Instead it exhibits a permanent deformation, which is a result of damage of the material in the vicinity of hinge *H*. This damage is referred to as plastic deformation, and it can result in fracture of the paper clip. One way that plastic damage can lead to failure of the paper clip is referred to as plastic collapse, and involves increasing the rotation about the hinge to a point that breaks the paper clip into two pieces. Another way is through so called low cycle fatigue, whereby the clip is subjected to repetitive cycles of counter-clockwise followed by clockwise rotations about the hinge. Below is a typical stress-strain curve for a ductile metal.

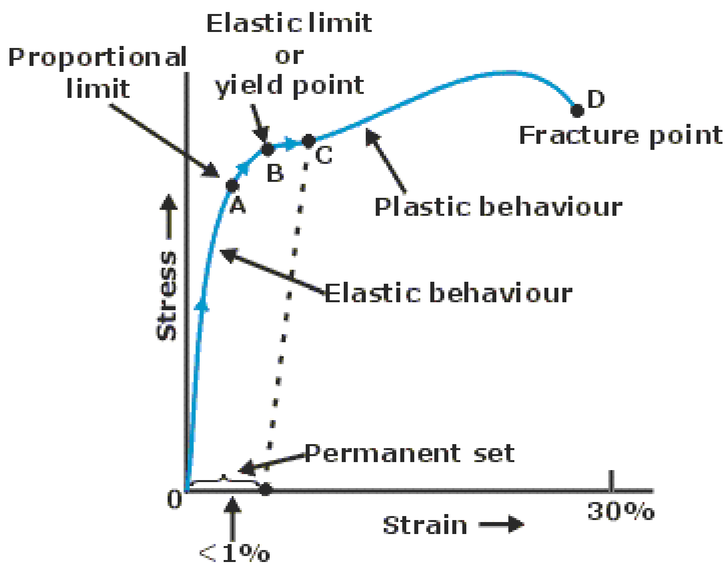

Figure 2: Typical stress-strain curve

2.1 Limit State Design

Limit state design of an engineering structure must ensure that under the worst loadings the structure is safe, and during normal working conditions the deformations members does not detract from the appearance, durability or performance of the structure. One of the principal types of limit state is the serviceability limit state. Serviceability refers to the conditions under which a building is still considered useful. A serviceability limit defines the performance criterion for serviceability and corresponds to a condition beyond which specified service requirements resulting from the planned use are no longer met. In limit state design, a structure fails its serviceability if the criteria of the serviceability limit state are not met during the specified service life and with the required reliability. Generally the most important serviceability limit states are:

1. Deflection: the appearance or efficiency of any part of the structure must not be adversely affected by deflections nor should the comfort of the building users be adversely affected.

2. Cracking: local damage due to cracking and spalling must not affect the appearance, efficiency or durability of the structure.
3. Durability: this must be considered in terms of the proposed life of the structure and its conditions of exposure.
4. Excessive vibration: this may cause discomfort or alarm as well as damage.
5. Fatigue: must be considered if cyclic loading is likely.
6. Fire resistance: this must be considered in terms of resistance to collapse, flame penetration and heat transfer.
7. Special circumstances: any special requirements of the structure which are not covered by any of the more common limit states, such as earthquake resistance, must be taken into account.

A structure that fails serviceability has exceeded a defined limit for one of the following properties:

- Excessive deflection
- Vibration
- Local deformation

2.2 Deflection Effects on Bridge

Deterioration of reinforced concrete bridge will reduces service life by reducing load capacity of the structure and the quality of the riding surface. It is good to know whether bridge deterioration is contributes to excessive bridge deflection. There are four main types of deck deterioration which is spalling, surface scaling, tranverse cracking and longitudinal cracking. Spalling is normally caused by corrosion of reinforcement and freeze/thaw cycles of the concrete. (Charles, Karl and Adam, 2002)

When there is reinforcement corrosion occurs, it will automatically affect the strength of the structure. Reinforcement corrosion induced structural failure does not necessarily imply structural collapse but in most cases manifest the loss of structural serviceability, as characterized by concrete spalling and the excessive deflection of concrete members. Whenever the state of stress in concrete reaches the ultimate tensile strength, it will crack due to the lack of ductility and because of that, it will be subjected to moisture which will contribute to corrosion. The most important cause of concrete cracking besides moisture is the formation of tensile stresses due to the different loadings from vehicles that affect the structure. Whenever a crack is formed in the concrete, it becomes a place for increase of the chloride and carbon levels around the steel rebars, and this will increase the rate of the corrosion process. If no prevention been taken, the process will continue until failures occur. As a consequence, the stiffness of the structure reduces and the deflection increases.

2.3 Vibration

Vibration can be stated as a mechanical phenomenon which oscillations occur about an equilibrium point. The oscillations may be periodic like the motion of a pendulum or random such as the movement of a tire on a gravel road. Usually, vibration will create unwanted sound or noise besides wasting energy and undesirable. Whenever there are moving vehicles which crosses the bridge, there will be a vibration produce especially on discontinuities surface like roadway approaches, deck joints or cracks surface.

When the structure start to vibrate, they tend to vibrate at a particular frequencies or a set of frequencies which known as natural frequency.

$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

While angular frequency, $\omega_o = \sqrt{\frac{k}{m}}$

Where, k=stiffness

m=mass

It can be seen that the frequency of the material when subjected to vibration will be affected by their stiffness and mass.

2.4 Human Response towards Vibration

Human sensitivity to vibration poses serious technical problems for engineers in various fields. In the field of transportation there is concern comfort in automobiles, civil aircraft, and in design of military aircraft for maximum efficiency. There is concern for the residents of houses that are subjected to vibration due to railway traffic and industrial machinery. One of the recent concerns of civil engineers has been the objectionable level of vibration on urban bridges used by pedestrians and vehicles. The nature of the problem is easy to grasp. It is readily apparent that there are both physiological and psychological reactions when humans subjected to vibration.

In cases where humans are disturbed by vibration of low frequency and large amplitudes, human reactions are basically physiological for example sea sickness. On the other hand, in cases where a person is subjected to unexpected vibration, for instance, when a pedestrian on a bridge experiences whole body vibration due to traffic crossing the bridge, his reaction may be totally psychological. In such case, a pedestrian may associate unexpected motion of the bridge with its poor design and possibly its failure, not knowing that this type of vibration is quite normal for the bridge. (John T. Gaunt and C. Doughlass Sutton, 1981)

2.4.1 Factors Affecting Human Comfort

Factors which affect human comfort can be divided into two groups. The first group includes human factors, such as weight, height and degree of exposure to vibration. For example, the people who are exposed to vertical vibration in their work tend to rate a given vibration less than people who are not exposed to vibration in their everyday lives.

The second group factors are related to the vibration, such as duration of exposure, amplitude, velocity, acceleration and jerk. John T. Gaunt had stated that the longer the duration of exposure the higher the uncomfortable rating.

2.4.1.1 Amplitudes

Some investigators have stated that above a certain frequency, only amplitude of the vibration affects discomfort.

2.4.1.2 Velocity

Hirschfield noted that “Human beings are not directly sensitive to velocity. They are sometimes indirectly sensitive, as when high velocity produces high wind pressure upon part of the body. If a person is carried in a completely closed box at a constant speed, he could not tell whether the box was standing or being moved at high speed. The reason for this is once we are in a motion at a constant speed, no force is needed to operate on us to keep us in such motion”. However, Janeway stated that at 20Hz to 60Hz, the thresholds are a function of velocity.

2.4.1.3 Acceleration

According to Hirschfield, “Conditions are quite different when velocity is being changed, and acceleration occurs. To produce acceleration a force must act upon us.” Many investigators reported that linear acceleration is detected by the otolith, a part of the inner ear. The threshold of these sensors to linear acceleration of long duration is about 0.0981 m/s^2.

2.4.1.4 Jerk

Once an adjustment is made by the human body for acceleration, the body will adapt to the constant force acting on it. However, with changing acceleration, continuously changing bodily adjustment is required. This rate of change of acceleration is also a critical component of motion comfort. Janeway concluded that at frequencies of from 1Hz – 6Hz the rate of change of acceleration rather than the acceleration itself is the cause for human discomfort.

CHAPTER 3: CODE OF STANDARDS AND GUIDELINES STUDY

3.1 AASHTO Standard Specification (1996)

3.1.1 Deflection Control

In structure design, deflection is one of important category of serviceability that needs to be considered because it is one of factors that can affect a structure's performance over the course of its service life. Deflection limits are employed for several reasons. The deformations under service load may cause damage to nonstructural bridge components like cracking in the wearing space. Deflections that caused from moving vehicles will produce vibration that can annoy the drivers or users and also will make the human psychologically think that the structure is unsafe.

The AASHTO Standard Specification (1996) recommends the use of deflection limitations when designing a structure for service live load and impact. Article 2.5.2.6 advises that the maximum deformation of a bridge should not exceed (Span Length)/800 for general vehicular bridges.

There are many research that had be done before to study on rationality of deflection limits in regards to human psychological element and structural deterioration. The result of mostly research efforts indicate that the current AASHTO serviceability deflection criteria is inadequate in controlling excess bridge vibration and structural deterioration.

Wright and Walker (1971) had concluded that live-load deflections alone are insufficient in controlling excessive bridge vibration. Another study from Amaraks (1975) used finite element models to determine what properties of bridges and traffic caused excessive vibration. By varying the parameters of span length, stiffness, surface roughness, axle spacing, number of axles, and vehicle speed, the study was able to determine which parameter affected the maximum acceleration of the bridge the most. From that, it had been determined that the largest factor was surface roughness. Besides the span length also one of the factors as the shorter the bridges the higher accelerations experienced. Stiffness also was a factor but less contribution than those two. Vehicle speed was another significant influencing factor on bridge accelerations. The finding that surface roughness is the largest factor in bridge accelerations was reinforced by another study (Dewolf and Kou 1997). Results from this study examined the effects of vehicle speed, vehicle weight, girder flexibility, deck thickness, and surface roughness on bridge accelerations. The accelerations for a rough surface were 1.75 times the accelerations for a smooth surface.

All of these studies show that the excess of vibration is caused more by the natural frequency of the bridge, vehicle speed and surface roughness than correlated to the deflection.

Besides, a study that had been conducted by Fountain and Thunman (1987) also had concluded that AASHTO live-load deflection criteria did not achieve the supposed goal for strength, durability, safety, or maintenance of bridges. Barth, Bergman and Roeder (2002) also had supported by conducted the studies and stated that for better controlled of bridge vibration by a limit based on a dynamic property of the bridge like natural frequency.

3.1.2 Dynamic Load Allowance

A certain dynamic properties between the vehicle and bridge will be produce whenever there are moving vehicles crosses the bridge which may cause an amplification of the static load effect from the wheel loads of the vehicle. This dynamic effect is causes when the wheel assembly rides on surface discontinuities like roadway approaches, deck joints or cracks. AASHTO takes these dynamic effects into account in the bridge design process by applying an impact factor to the static wheel loads. The AASHTO Standard Specification for Highway Bridges (1996) allows highway wheel loads to be increased to account for dynamic, vibratory and impact effects for certain structural elements. Section 3.8.2 specifies the impact equation as follows to the applicable structural elements:

$$I = \frac{50}{L + 125}$$

Where I is the impact factor, L is the length in feet of the portion of the span that is loaded to produce maximum loading effect on the member. For a simply supported bridge, L is essentially the span length measured from centerline of support. The impact allowance may not exceed 1.3, which would be a maximum 30% increase in live load (AASHTO, 1996).

3.2 Vibrar units

A number of units have been suggested for defining the intensity of vibration. These units have been related to the physiological effects of vibration and to effects on building structures. Vibrar units is a useful one for making comparisons between the effects of vibrations having different amplitudes and frequencies.

3.2.1 Vibrar Rating by (Koch, 1953)

A rudimentary scale was produced (Koch, 1953) using Vibrar units. The calculation of the strength of vibration in Vibrar units is:

$$V = 10 \log_{10} (160.\pi^4.A^2.f^3)$$

Where:

A is the maximum amplitude in centimeters
f is the fundamental natural frequency
V is the strength of the vibration

Strength of vibration (Vibrar)	Type	Damage
10-20	Light	None
20-30	Medium	None
30-40	Strong	Light (non structural cracking)
40-50	Heavy	Severe (damage to structural elements)
50-60	Very heavy	Collapse

Table1: Vibrar rating of vibration intensity [Koch, 1953]

The rating on the Vibrar scale clearly correlates well with the necessities of the decision making process. A state of collapse prevention implies a Vibrar rating of just below 50, whilst a rating of immediate occupancy would be indicated of the Vibrar rating is below 40. (Alan P. Jeary)

3.2.2 Zeller's Power of Vibration

A study of vibration testing by M. J. O' Dogherty had used Zeller's Power of Vibration to detect the vibration occur on the building.

Zeller's power of vibration, Z, is defined as:

$$Z = \frac{\hat{\alpha}_o^2}{f} = 16\pi^4 a_o^{\ 2} f^3$$

Where $\hat{\alpha}_o$ is the maximum acceleration = 4 $\pi^4 a_o f^2$

f is the frequency of vibration

a_o is the maximum amplitude of vibration

The "vibrar" unit is a useful one for making comparisons between the effects of vibrations having different amplitudes and frequencies. The unit is derived in terms of Zeller's power,

Strength of vibration (vibrars) =10 $\log_{10} \frac{Z}{Z_o}$

where Z_o has the value 0.1cm²/sec³ in metric units

substitute Z_o, strength of vibration (vibrars) = 10 $\log_{10}$ 10Z

= 10 + 10 $\log_{10}$ Z

The investigations of vibrations have led to classifications of the intensity of vibration and its possible effects (Koch, 1953)

Strength of vibration (Vibrar)	**Type**	**Damage**
10-20	Light	None
20-30	Medium	None
30-40	Strong	Light (non structural cracking)
40-50	Heavy	Severe (damage to structural elements)
50-60	Very heavy	Collapse

Table2: Vibration Intensity and Probable Damage

Zeller also had drawn up a table relating the strength of the vibration to its effects and this is given in table below:

Zeller's value (Z) (cm^2/sec^3)	**Rating or grade**	**Assessment (effect on buildings)**
1	1	Not perceptible
2	2	Very light
10	3	Light
50	4	Measureable (small cracks)
250	5	Fairly strong
1,000	6	Strong – beginning of danger zone
5,000	7	Very strong – serious cracking
20,000	8	Destructive
100,000	9	Devastating

Table3: The Zeller scale of vibration effects

The value of Z = 5,000, which represents the onset of serious damage corresponds to 47 vibrars, and the criterion for a destructive vibration (Z = 20,000) corresponds to 53 vibrars. (M. J. O' Dogherty)

Figure below shows the classification of vibration intensity which plotted as a relationship between amplitude and frequency range 1-100 Hz.

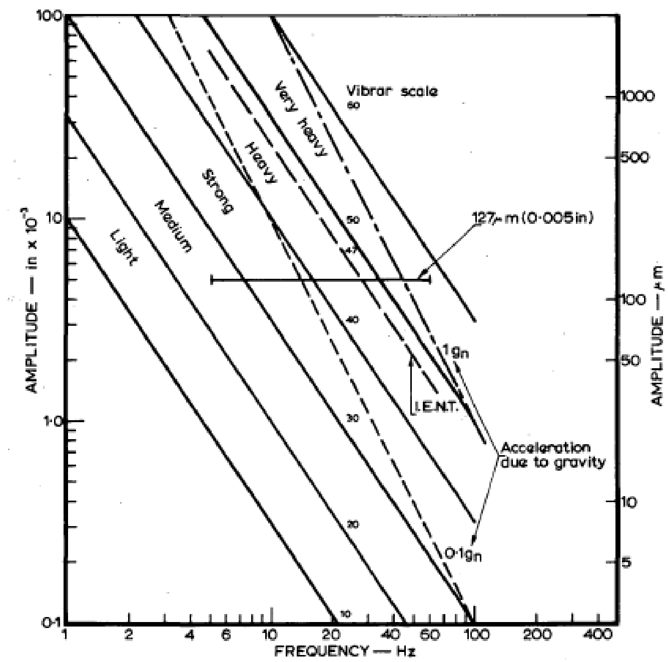

Figure 3: Classification of vibration intensity

3.3 Wright and Walker Study

A study that had been done on 1971 by the American Iron and Steel Institute (AISI) which review the AASHTO criteria and had recommend relaxed design limits based on vertical acceleration to control bridge vibrations. (Wright and Walker, 1971)

The acceleration limit must not exceed the limit which *a* = 100 in/sec² which dynamic component of acceleration, *a* (in/sec²) is formulated as:

$$a = DI\ \delta_s\ (2\pi f_b)^2$$

while the impact factor, $DI = \alpha + 0.15$

speed parameter, $\alpha = v/(2 f_b L)$ where v = vehicle speed,fps

natural frequency, $f_b = (\pi/2L^2)(E_b I_b g/w)^{1/2}$ *(unit cps)* computed for simple or equal spans static deflection, δ_s is the deflection as a result of live loads, with a wheel load distribution factor of 0.7, on one stringer acting with its share of the deck.

If the Dynamic Component of Acceleration exceeds the acceleration limit, a redesign is needed.

3.4 ISO 2631-1

This ISO standard had provides evaluation methods for quantifying the level of vibration. ISO 2631-1 stipulate the use of a weighted acceleration time history based on a frequency weighting, Wk for vertical vibration. This frequency weighting takes into account how the human body responds to the varying frequency content of vibration. The human body is more sensitive to vibration in the 4-8Hz range as the natural frequency of the internal organs of the body lie in this range.

The ISO standard specifies a basic evaluation method using the weighted root-mean-square acceleration. This RMS measurement can be calculated using this formula:

$$a_{rms}(T) = \left(\frac{1}{T} \int_0^T [a_w(t)]^2 dt \right)^{\frac{1}{2}}$$

$$a_{rms} = \left(\frac{1}{N} \sum_{i=1}^{N} a_i^2 \right)^{\frac{1}{2}}$$

where $a_w(t)$ is the weighted acceleration as a continuous function dependent on time

T is the duration of the measurement

$a_i(t)$ is a digitized sample of the weighted acceleration

N is the number of points in the digitized sample

a_{rms} is expressed in units of m/s^2

For assessment of the effects of vibration on comfort and perception as expressed in the ISO standard, guidance is provided in terms of r.m.s acceleration, as shown in the table below:

Level of r.m.s acceleration (m/s²)	**Perception and comfort level**
< 0.315	Not uncomfortable
0.315 – 0.63	A little uncomfortable
0.5 – 1	Fairly uncomfortable
0.8 – 1.6	Uncomfortable
1.25 – 2.5	Very uncomfortable
< 2	Extremely uncomfortable

Table 4: RMS acceleration ranges for levels of perception (ISO 2631)

CHAPTER 4: METHODOLOGY

4.1 Project Flowchart

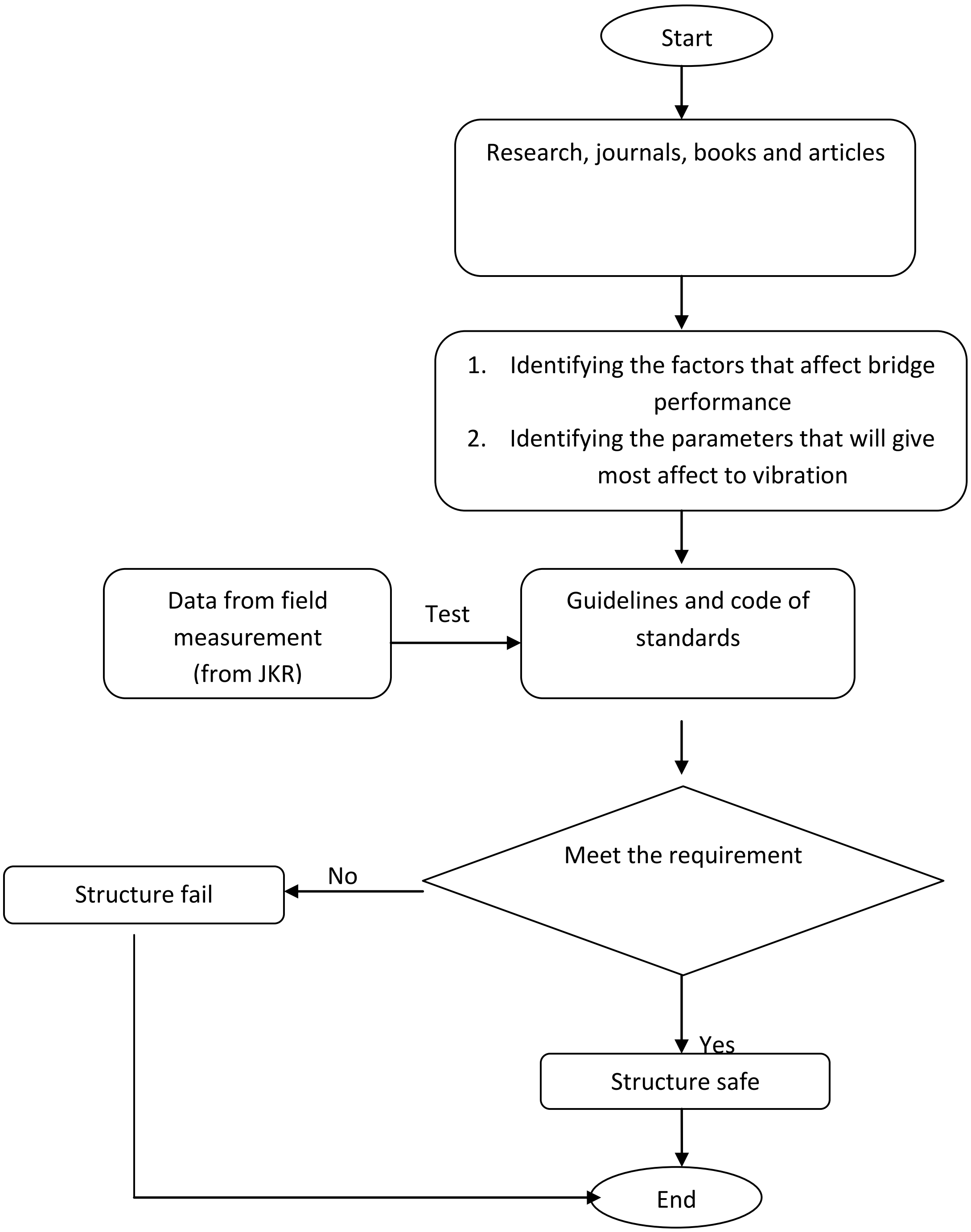

Figure 4: Flowchart for FYP I and FYP II

4.2 Project Planning

The research or study on reliability of the structure and factors that affect the bridge performance had been carrying out to know the dynamic criteria of the bridge. Based on the study, the author had specified the criteria that important and gives higher effect to the performance of the bridge which is deflection, acceleration and frequency. After that, based on the data gathering from field measurement from JKR on MRR2 bridge, the test will be carrying out based on standards and guidelines that had been choosen to identify whether the bridge is safe or not.

4.3 Data Testing

The data that collected from the JKR had been testing to check with the Code of standards and guidelines that had been recognized whether it meet the requirement in order to identify the safety of the bridge.

4.4 Gantt Chart

Several targets have been set for FYP I and FYP II. Figures below show the project activities and the key milestones.

No.	Detail/ Week	1	2	3	4	5	6	7	M	8	9	10	11	12	13	14
1	Selection of Project Topic	■							I							
2	Literatures Review		■	■	■	■			D							
3	Submission of Extended Proposal						○									
4	Research on the reliability of a structure, structure performance, design parameters							■	S E	■						
5	Proposal Defense								M		○					
6	Study on vibration of the structure, reliability analysis								B			■	■	■	■	
7	Submission of Interim Draft Report								R						○	
8	Submission of Interim Report								E A K							○

Legends:

■ Project Activity

○ Key Milestone

Figure 5: FYP I Project Activity and Key Milestone

No.	Detail/ Week	1	2	3	4	5	6	7	M	8	9	10	11	12	13	14	15
1	Research on Bridge Reliability Index	■	■	■	■	■	■	■	I	■	■	■	■				
2	Submission of Progress Report								D	○							
4	Test the data measured from JKR based on BRI, result and conclusion making								S				■	■			
5	Pre-EDX								E				○				
6	Submission of Draft Report								M					○			
7	Submission of Dissertation (soft bound)														○		
8	Submission of Technical Paper								B						○		
9	Oral Presentation								R							○	
10	Submission of Project Dissertation (Hard Bound)								E A K								○

Legends:

■ Project Activity

○ Key Milestone

Figure 6: FYP II Project Activity and Key Milestone

CHAPTER 5: RESULTS AND DISCUSSIONS

These results are based on ISO 2631-1 standard, which provides evaluation methods for quantifying the level of vibration. For this study, only the vibration in the z-direction or vertical direction will be considered.

The data of acceleration that got from the field measurement had been analyze in order to check the level of vibration to human comfort. Point SA and SB is the measurement taken on the span while RA and RB is on the pier of the bridge.

POINT SA

Point	**a_{rms} (m/s²)**	**Observation**
SA1	0.021	Not uncomfortable
SA2	0.022	
SA3	0.028	
SA4	0.018	
SA5	0.0153	
SA6	0.0165	
SA7	0.0149	
SA8	0.0130	

Table 5: Observation at Point SA

POINT SB

Point	**a_{rms} (m/s²)**	**Observation**
SB1	0.0332	Not uncomfortable
SB2	0.0219	
SB3	0.0318	
SB4	0.0202	
SB5	0.0266	
SB6	0.0346	
SB7	0.0341	
SB8	0.0163	

SB9	0.0330	
SB10	0.0259	
SB11	0.0393	
SB12	0.0498	

Table 6: Observation at Point SA

POINT RA

Point	**a_{rms} (m/s²)**	**Observation**
RA1	0.0102	Not uncomfortable
RA2	0.0102	
RA3	0.0037	
RA4	0.0024	
RA5	0.0098	
RA6	0.0059	
RA7	0.0074	
RA8	0.0014	
RA9	0.0068	
RA10	0.0053	
RA11	0.0077	
RA12	0.0068	
RA13	0.0025	
RA14	0.0055	
RA15	0.0151	

Table 7: Observation at Point SA

POINT RB

Point	a_{rms} (m/s^2)	Observation
RB1	0.0029	Not uncomfortable
RB2	0.0013	
RB3	0.0016	
RB4	0.0021	
RB5	0.0031	
RB6	0.0031	
RB7	0.0030	
RB8	0.0025	
RB9	0.0027	
RB10	0.0035	
RB11	0.0064	
RB12	0.0046	
RB13	0.0100	
RB14	0.0044	
RB15	0.0050	
RB16	0.0096	
RB17	0.0076	
RB18	0.0045	
RB19	0.0034	
RB20	0.0038	

Table 8: Observation at Point SA

From the results above, it shows that the level of r.m.s acceleration is less than 0.315 which still under comfortable level. As can be seen, the results observation for point SA and SB are more higher than point RA and RB because the measurement for SA and SB were doing on span of the bridge while point RA and RB were measured on the pier of the bridge which the span was produced more response on the vibration rather than pier of the bridge. Since the human reactions to vibration can be affected by psychological, they tends to feel that the structures are not safe when they expose to extraordinary vibration which actually just a normal vibration which not results on durability failure. From the studied before, they had said that psychological discomfort was affected most by acceleration since it is results from unexpected motion which the activity a person is performing affects the acceptable level of acceleration the person is able to tolerate.

CHAPTER 6: CONCLUSION

As a conclusion, this project has reached to the research on the reliability of a structure, structure performance, design parameters and study on vibration of the structure and reliability analysis which is line with the planned schedule. A few parameters had been recognized that had effect bridge performance which is deflection, accelerations and frequency. Since there was no direct provision in design codes to ensure user comfort and structure dynamic response, another methods or guidelines are needed to measure the comfort level and strength of the bridge. A few guidelines had been recognized in measuring the vibration of the structure which is Vibrar Rating by (Koch, 1953), Zeller's Power of Vibration, and study by Wright and Walker. Besides, AASHTO Specification Standards also can be used to measuring the deflection of the structure in order to check the serviceability. While ISO 2631-1 standards can be used to measure the level of human comfort by using r.m.s acceleration level. From the results that had been obtained, author can conclude that the MRR2 Bridge is still in comfortable level but for recommendation, the measurement on physiological effects of vibration can be done on the bridge to identify the strength of vibration and the level of damage of the bridge by using the frequency and amplitude parameters.

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