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And Scientific Research
University of Diyala
College of Engineering

FATIGUE PERFORMANCE OF AL-SABTEA BRIDGE UNDER THE EFFECTS OF DYNAMIC VEHICLE LOADS

A Thesis Submitted to the Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

By

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بسم الله الرحمن الرحيم

قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

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الآية (32)

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We certify that we have read the thesis entitled **(Fatigue Performance of AL-Sabtea Bridge Under the Effects of Dynamic Vehicle Loads)** and we have examined the student **(Qassim Yehya Hamood)** in its content and what is related with it, and in our opinion, it is adequate as a thesis for the degree of Master of Science in Civil Engineering.

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Date: 31 / 1 / 2019

Dedication

To:

My father

My mother

My wife, who supported me and who was the cause of my success

My sons and daughter whose love flow in my veins

Everyone, who wishes me success in my life

I dedicate this humble work.

ACKNOWLEDGMENT

*My great gratitude is to **Allah** the most gracious the most merciful who gave me enough strength to fulfill my study and work.*

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Researcher

Qassim Yehya Hamood
September 2018

Fatigue Performance of AL-Sabtea Bridge Under the Effects of Dynamic Vehicle Loads

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ABSTRACT

Composite bridge consists of different materials such as the girder made of steel or precast that connected with deck concrete slab by means of shear connectors to work as one. In the present study, AL-SABTEA composite bridge in Diyala, Iraq that was designed and constructed inherently to work as full interaction. The interior composite concrete steel girder is selected as a case study because it represents the worst case. Representation of composite steel bridge throughout the present study was done using finite elements approach by ANSYS software with different parameters to assess the efficiency of the composite bridge under the effects of static based on Iraqi and AASHTO specifications as well as dynamic and fatigue loading according to AASHTO specification using actual dimensions and mechanical properties.

Push-out test was also done to compare displacement results with the model established by ANSYS which proved that the proposed numerical model can represent the shear connector's behavior. It is recognized that the difference in the results of displacement of the latter comparison is small (5%) between experimental test and ANSYS model.

The effect modelling of shear connector was studied by the representation of channel shear connectors through elements of COMBIN39 element in comparison with using solid elements. The deflection difference between these two models is also small (2.5% to 3.7%).

The results showed that the deflection and stresses according to the Iraqi specification are more than AASHTO specification but still within permissible safe limits, furthermore, dynamic analysis which was done with different truck loading and velocity speed showed that truck HS20 gives deflection and stresses more than other trucks. In addition, as the velocity increases, the deflection and stresses under the effect of a specific load increase, due to increase in kinetic energy.

The fatigue analysis results indicated that the damage index at top face of the concrete deck slab, interface between concrete and steel girder and at bottom of steel flange girder for all load cases do not reach to unity and the maximum value is less than 0.2% in the case of HS20 loading. The fatigue damage at present time for Al-SEBTEA bridge if checked by adopting any methodology do not also reach 0.0045 for 10 years. The worst case of analysis result indicated that the maximum damage index occurs in the bottom face of composite steel girder that represent accumulative fatigue at this point.

Visual basic code was written as analytical solutions to calculate the number of shear connectors under the effects of static and fatigue loadings and also estimate the number of cycles during the bridge life. The relationship between the fatigue stress with stress ratio appeared as the fatigue stress increase when the stress ratio increase in a positive direction that is mean in the range of $R \geq 0$ up to 1. The fatigue stress increases with the decrease in reverse stress ratio in the range of (-1) up to zero in case of $R=0$.

In final assessment the results of deflection and stresses and fatigue stress within permissible are limited according to AASHTO code for all models.

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List of symbols and terminology

Symbol **Description**

$\{a\}$ = Vector of nodal displacement for the structure.

A_s = Total area of the steel section including.

A_r = Total area of longitudinal reinforcing steel within the effective flange width.

$[B]$ = Strain-nodal displacement matrix.

b = Effective flange width

c = Thickness of the concrete slab

[C] = Damping matrix.

$[D]$ = Constitutive matrix.

D = Damage accumulation factor.

dV = $(dx\ dy\ dz)$ volume of element.

E_c = Elasticity modulus of concrete.

$\{Fa\}$ = vector of applied loads.

$\{F\}$ = nodal forces.

{F (t)} = load vector.

f'_c = Specified compressive strength of concrete for cylinder at 28 days

f_r = specified minimum yield strength of the reinforcing steel

f_y = Specified yield stress of non-prestressed steel reinforcement

h = average flange thickness of the channel flange

[K] = stiffness matrix.

$[Ke]$ = element stiffness matrix.

[M] = mass matrix.

$[N]$ = shape function.

N_i = numbers of cycle.

P = force in the slab taken as the smaller value of the formulas.

S_u = ultimate strength of the shear connecter.

S_r = range of horizontal shear per linear length.

S = spacing between connectors center to center.

t_w = thickness of the web of a channel.

$\{U\}$ = body displacements (global displacements).

$\{\ddot{u}\}$ = nodal acceleration vector.

$\{\dot{u}\}$ = nodal velocity vector.

$\{u\}$ = nodal displacement vector.

$W_{int.}$ = internal work.

$W_{ext.}$ = external work.

W = length of a channel shear connector.

B = factor depends on the numbers of cycle.

Z_r = allowable range of horizontal shear.

$\{\varepsilon\}$ = strain vector.

$\{\sigma\}$ = stress vector.

$\{\delta a\}$ =vector is a set of arbitrary virtual.

ε_1 = Strain corresponding to $(0.3f'_c)$.

$\varepsilon_\circ$ =Strain at peck point.

ε_{cu} = Ultimate compressive point.

ni = Number of applied load cycle for a given stress range.

N_i = Number of resisting load cycle for a given stress range.

$\Delta\sigma$ = direct stress range.

$\Delta\sigma_c$ = reference stress value of the fatigue strength at 2 million cycles.

$\Delta\sigma_D$ = reference stress value of the fatigue strength at 5 million cycles.

$\Delta\sigma_L$ = stress value of the fatigue strength at cut-off limit.

γ_{mf} = partial factor for fatigue strength.

γ_{Ff} = partial factor for equivalent constant amplitude stress ranges.

m = slope of fatigue strength curve.

Symbol		Description
ACI	:	American Concrete Institute.
ASCE	:	American Society of Civil Engineers.
D.O.F.	:	Degree of freedom.
FBD	:	Free Body Diagram.
F.E.A.	:	Finite Element Analysis.
Fig.	:	Figure.
No.	:	Number (issue).
pp.	:	Pages.
R.C.	:	Reinforced concrete.
Ref.	:	Reference.
Vol.	:	Volume (issue)
DIF	:	Dynamic increment factor.

CHAPTER ONE

INTRODUCTION

1.1 General

Girder bridges system is structurally containes girders as steel or precast reinforced concrete connected to reinforced deck slab and adopted on short to medium span bridges.

The term composite structure means that two or more different structural elements connectd to each other to form one structural element such as composite bridge contines steel or precast girders and concrete slab. The relations between the different elements differes according to modulus of elasticity and Poission's ration as partial or full interaction theory.

The bridge Al-SABTIA is construction On the Diyala River, the road to Baghdad-Muqdadiya. Between intersection of Al-Quads and the intersection of Imam Abdullah bin Ali. History of construction of bridge at 1979-1981. This exposure to the bridge bombing led to the collapse of the entire space of a length of 36 meters and has space to rehabilitate the collapsed bridge, which is the subject of study. The length of the part that has been rehabilitated 36 meters and width 21 meters.

Fatigue of the structural elements that fail due to the cumulative damaged by the connected between the microscopic interior cracks represents the main problem of structure such as bridges. The source of fatigue in bridges is amplitude dynamic loading from vehicles during the service life of the bridge that cause fatigue. The repeated load that applied on the bridge developed micro cracks and lead to serious fatigue failures. The effect of dynamic vehicle loading on the fatigue life of Al-SABTIA Bridge shown in Plate (1.1) as a case study to evaluate and check-the performance of bridge.

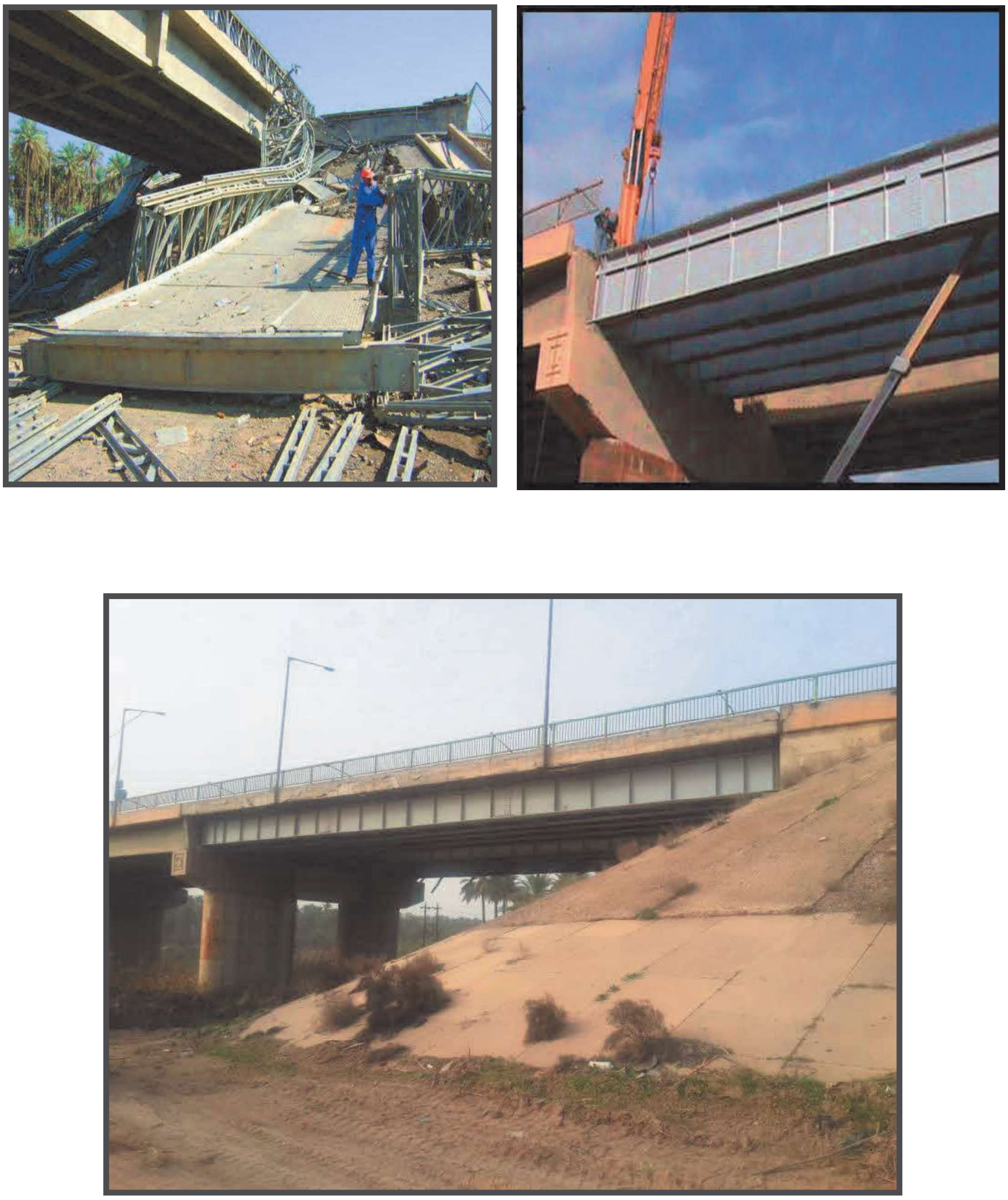

Plate 1.1: View of Al-SABTIA Bridge

1.2 Composite members

The composite structures have advantages such as reducing in dead load and more durable with benefit of concrete in compression and the steel in tension that is connected by means of mechanical anchorage of shear connectors. The composite action is defined as the interaction of different structural elements, the types of composite structures shown in Figure (1.1) (Abdul kaliq, 2011).

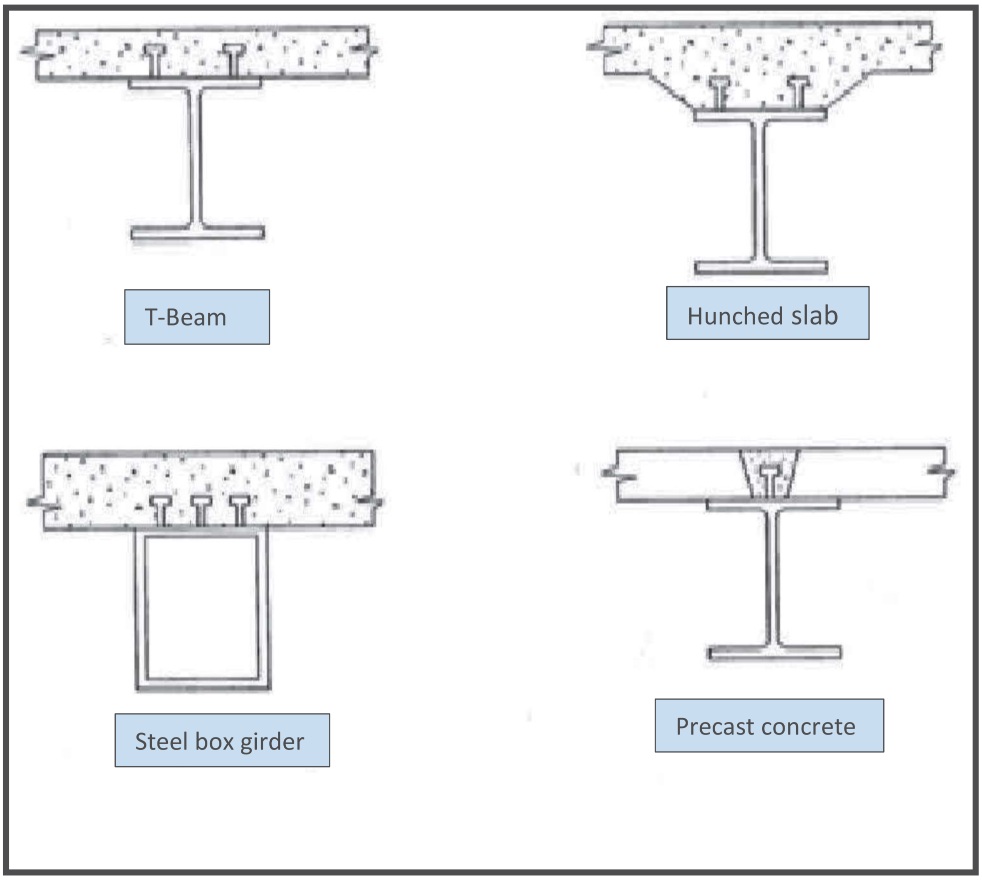

Figure 1.1: Types of composite members (Abdul Ridah, 2011).

1.3 Composite Action

There are mainly two types of composite action, as shown in Figure (1.2) and (1.3).

Complete (or Full) Interaction: It is an infinitely stiff shear connection, no slip and slip strain, plane sections remain plane with regard to resistance, and the connection is considered to be complete if the resistance of the composite beam is decided by the bending resistance, not the horizontal shear resistance (Hechlera, 2008).

Partial Interaction: It is the provided shear connectors are less than the shear connectors required to behave full but within standard limits. The slip and slip strain will develop (Hechlera, 2008).

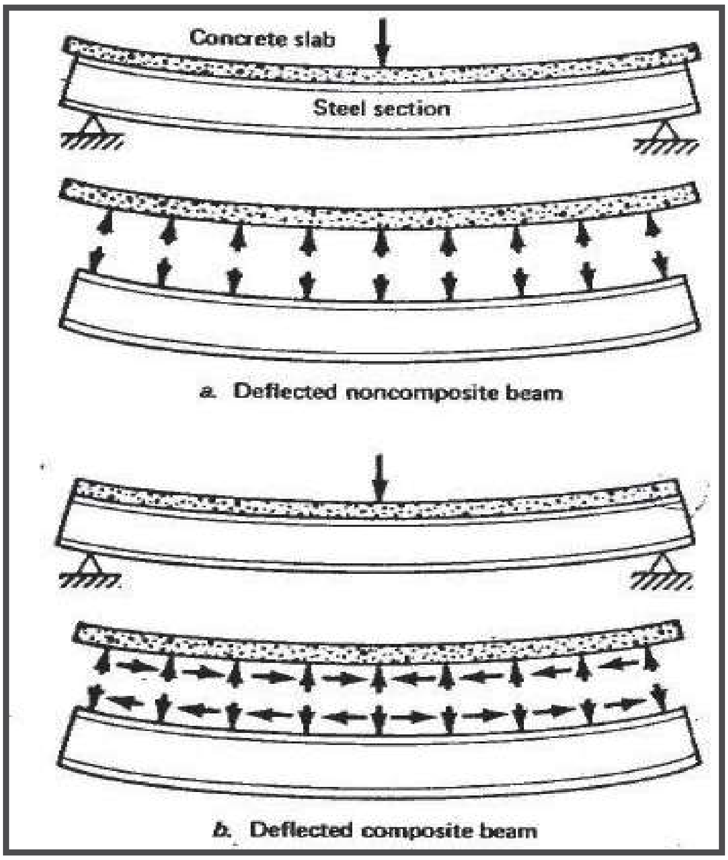

Figure 1.2: Comparison of deflected beams with and without composite action (Hechlera, 2008).

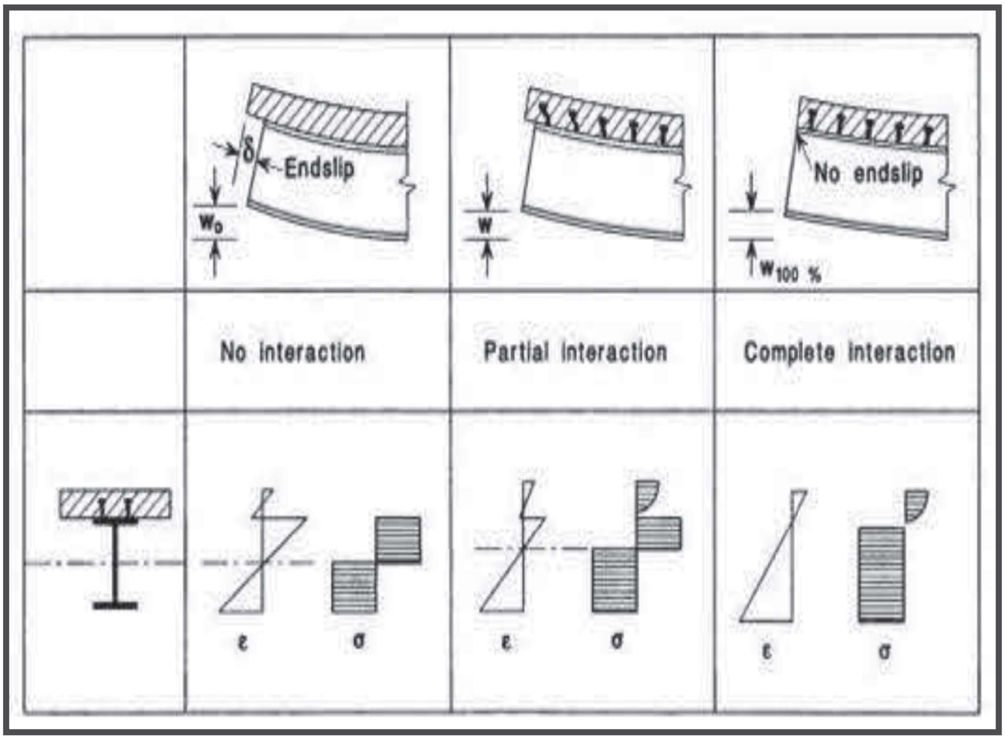

Figure 1.3: Composite steel beam-concrete slab interaction (Hechlera, 2008)

1.4 Shear Connection

Shear connectors were adopted to develop the composite action between steel sections or girders and deck slab. Different types of shear connectors such as the channel or stud connector can be adopted that available in market as shown in Figure (1.4). The connectors can be also classified as either rigid type (non-ductile) or flexible type (ductile) ,depending on the functions between strength and deformations, and the distribution of shear forces (Al-Darzi S. Y. K., and Chen A., 2006). The main functions of shear connectors are to resist longitudinal shear, transfer shear, create a tensile link into the concrete and uplift force (Walbrun, 2006).

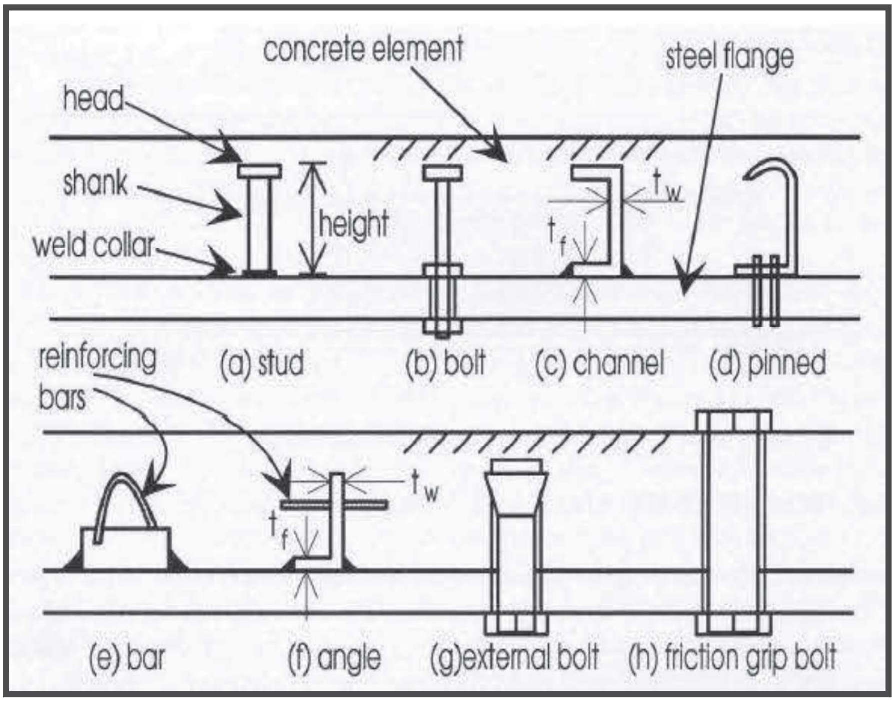

Figure 1.4: Various Types of Shear Connector (Oehlers, 1999)

1.5 Fatigue

Fatigue of the structural elements is the failure which occurs at stress levels below yield stress of the material due to the cumulative damaged by applied repeated loadings (Truck loading). The connection between the microscopic interior cracks represents the main problem of the fail structure such as bridges. The source of fatigue in bridges is amplitude repeated loading from vehicles during the service life of the bridge.

Different approaches adopted to estimate the fatigue life and the maximum stresses due to applied loadings such as Euler- Bernoulli theory and Fourier series as analytical solution and also numerical analysis by using finite elements approach.

1.6 Factors Governing the Fatigue Life

Different parameters that effects on the fatigue life of any materials when subjected to fatigue load such as mechanical properties, stiffness, stress range and amplitude stress. Residual stress also is an important parameter that in both increasing and decreasing the fatigue life especially in case of stress ratio in negative. The load range shown in Figure (1.5). Peak load (P max) is the maximum load applied to a load cycle. The peak load affects the life of a structure, but it does not affect the rate of degradation. (Kayir, 2006).

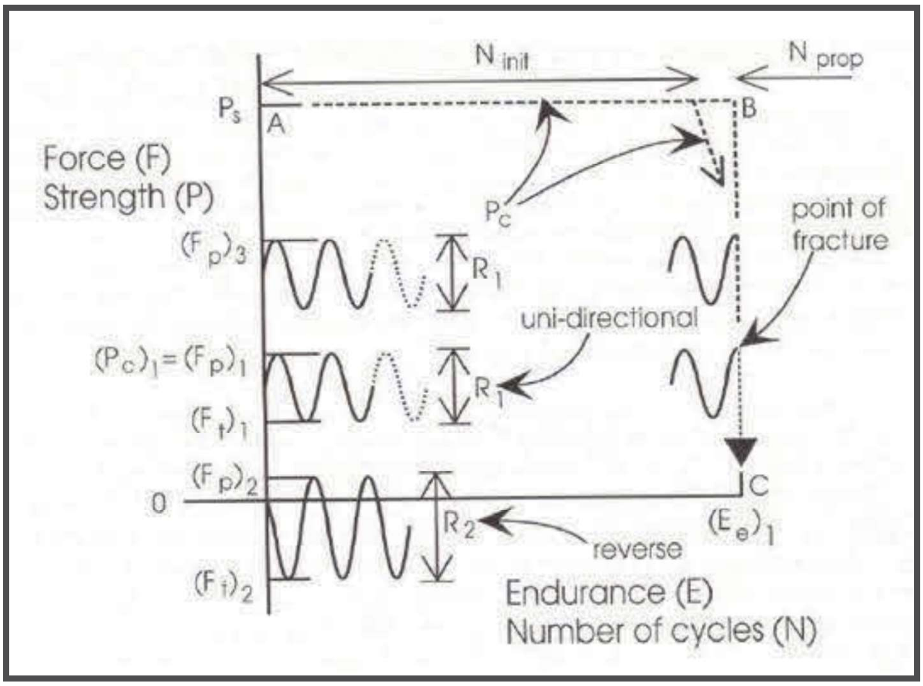

Figure 1.5: Schematic of fatigue strength during fatigue testing (Kayir, 2006).

1.7 Objectives

The aim of the present study is to evaluate the fatigue performance and strength of existing of Al-SABTIA composite bridge constructed in Diyala-Iraq. Hence, the study aims at:

1- Simulating of composite steel girder Al-SABTIA bridges using finite element approach by ANSYS**.**
2- Evaluating the performance of composite steel girder under static loads according to the specification of AASHTO and Iraqi specification road and bridge taking into account the partial and full interaction behavior at the interface between top steel girder and the bottom reinforced concrete slab.
3- Evaluating fatigue damage performance of composite steel girder by simulation Al-SABTIA bridges by program computer of finite element (ANSYS) under dynamic moving loads based on AASHTO load under the effects of velocity speed in terms of low, medium and high.
4- Constructing design chart for composite steel girder for the fatigue stress that developed in the bridge due to apply external loading.
5- Constructing design chart for composite steel girder for the variation of horizontal shear range with differences of number of cycle and spacing the center to center of shear connector.

1.8 Thesis Layout

Six chapters are suggested and bestowed in the present study:

1. **Chapter One:** Exhibit an introduction to composite structures, fatigue damage and objectives of this research work.
2. **Chapter Two:** It displays the literature review of the previously works of the fatigue resistance of composite steel-concrete and their behavior under cyclic loading.

3. **Chapter three**: Theory of composite steel girder, loading of dynamic and fatigue and numerical modelling of finite element.
4. **Chapter four**: Experimental work of push out test and validation.
5. **Chapter five**: Results and discussion of the composite concrete steel girder under static, dynamic and fatigue analysis.
6. **Chapter six**: Conclusion from this study, recommendation and suggestions for future work.