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Study the Structural Behavior of Buildings Susceptible To Vibration Due To Road Bumps

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ABSTRACT: Vibration generated due to road bumps has a significant effect on the behavior of nearby buildings; this must be taken into account during design. This paper includes the study of the behavior of buildings through the stresses in it. Therefore, two types of buildings were used, one structural building and the other is brick building (nonstructural) and these buildings are two types one and two floors. The soil was taken sand and clay soil to indicate the type of soil suitable for that absorption of vibrations. ANSYS program is used to analyze the problem and study some variables affected on the behavior of buildings, such as the speed and mass of vehicles, the type of road bumps (plastic, Asphalt and concrete), the width of the road bump and the distance between the building and road bumps .

The study indicated that the brick buildings with one floor and based on sand soil are more effected to cracks and that the size of the crack and the quantity of the stresses are proportional to the mass and velocity of the vehicle and inversely with the distance from bumps to the building and the width of the bump and the plastic bumps have the least influence on the behavior of buildings.

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I INTRODUCTION

For the most part, buildingsare subjected to vibration due to traffic or street bumps that causeseffect on the structural behavior, sometimes causing visible cracks or failure inside the building, the vibration is very dangerous and undesirable by humansbecause it effects on their well being.

This paper studies the effect of vibration on the behavior of buildings and gives some practical solution to reduce this effect. This vibration is produced by contact, andresonant frequencyand noise may behappen.Vibration due to street bumps has become important with high speed of vehicles. In Iraq, a high-speed vehicle needs to be discussed with the increasing number of road bumps, especially with the development of projects [1], [2].

A large amounted research shows the relation between the speeds and correct spacing and dimensions of road bumps to limiting and reducing the vehicle speed. Bumps designed to give comfortably to the vehicle which is safe and desirable under certain circumstances, while the higher speed causes discomfort for driver [3].

The random and discrete bumps in the street surface lead to dynamic interaction forces between street and tires of vehicle. These forces produce stress in the soil which induces vibration in approaching buildings. The forces are divided into two parts according to a surface irregularity which encountering the vehicle: (1) primary impact force, and (2) periodic force in 'axle hop'. The primary impact force induces surface vibrations which controls to the natural frequencies of the soil. On the other hand, the force produced by the axle hop is inducting surface vibrations at the hop frequency which is calculated by the properties of the vehicles. In Montreal, a recent study on the vibration of buildings caused by traffic shows the phenomenon above. For example, buses produce surface vibrations greater than those produce by trucks with the same weight, the frequency of vibrations produced by these types is not same, and this frequency in different site which is very small [4].

This paper studies the behavior of buildings according tovibrations due to bumps. Structure and non-structure buildings are takenin account. ANSYS software is used to analyze the problem, with several parametric studies.

II PROBLEM DESCRIPTION

Figure (1) illustrated the building which is subjected to vibration load due to movement of vehicles above the bumps in the street. In this research, two types of buildings will be studied, the first is a structural building but the other is a non-structural building.Also the building consists of one or two floors, the building is based on clay or sand soil. The road bumps were taken with different widths (W) (0.5, 3and 7 m) and different materials (plastic, concrete and asphalt). Vehicles were taken in three types: cars, small vehicles and long vehicles. The distance (D) between the street and the building was imposed (5, 10, 25, 50 and 75 m).

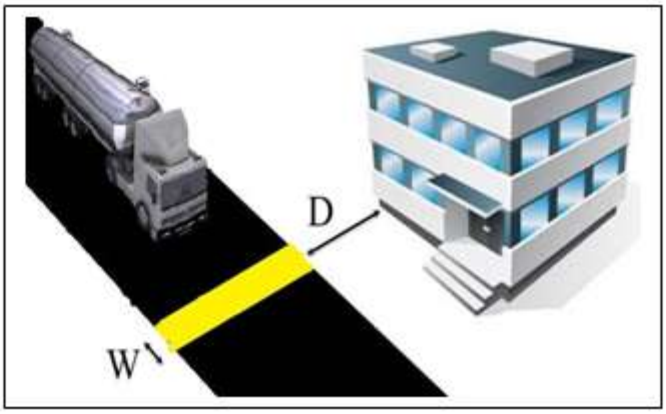


Figure (1): Problem Description

III FINITE ELEMENT ANALYSIS

ANSYS finite element package was used in the analysis. It is applicable to solve the problem in linear and non-linear and it has different elements that are used to represent the structureFigure (2) shows the 3D modeling of problem in ANSYS [5].

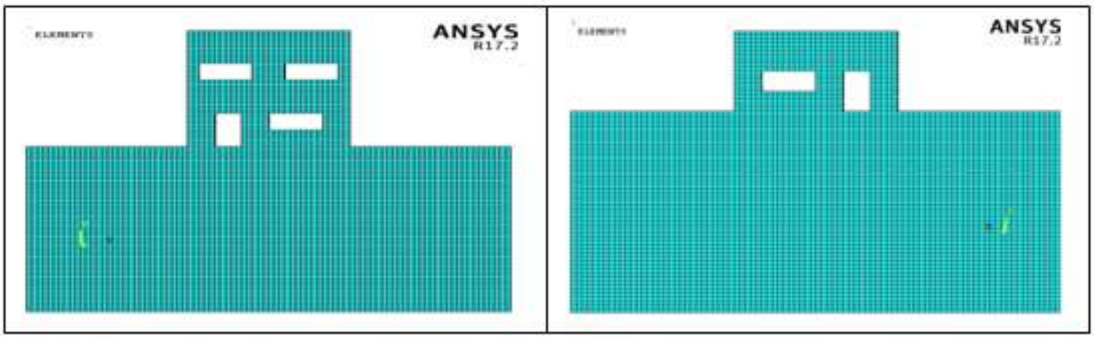


Figure (2): Structural Modeling in

Concrete element was represented by SOLID65 element. It has eight nodes, each node has threetranslational degrees of freedom in x,y and z. The element was capable of plastic deformation and cracking.Table (1) showsthe properties of concrete element.SOLID 185 and SOLID 45 were used for modeling the masonry brick and cement mortar joint respectively. These have eight nodes with threetranslational degrees of freedom, the element is able to simulate the deformation and there have hyper-elasticity, plasticity, creep, large strain stress stiffening and large deflection, Table (2) reviews the engineering properties of masonry brick and Table (3) represents the characteristic of cement mortar. The soil was modeled as an elastic-plastic Mohr column model by using the eight nodes brick element with three translational degrees of freedom.Table (4) shows the geotechnical properties for thesand and clay soil used in the analysis.Solid 5(8 nodes brick element)was used to simulatestructural properties of pavement slab.Solid185elementis used as a model the rubber material that used to model the road bumps, Table (5) shows the pavement and the rubber data used for rad and road bumps. The domain of soil is extended to 5 foundation widths from center of building foundation and 5 pavement widths measured from the center of pavement, and uses fixed boundary condition for all sides. Perfect bond is used to represent the connections in problem. The Dynamic load applied on bumpis shown in Figure (4) dependent on type of vehicle.

Table (1) The Properties of Concrete Element.

Elastic modulus (GPa)	Poisson's ratio (ν)	Ultimate uniaxial tensile strength (ft) MPa	Ultimate uniaxial compressive strength (fc) MPa	Maximum tensile strength (ε_{tu})
220	0.3	2.1	21	0.0015

Table(2) The Engineering Properties of Masonry Brick

Density (gram/cm^3)	Dimension l . w . t (cm x cm x cm)	Elastic modulus (MPa)	Poisson´s Ratio	Modulus of Rupture (kg/cm^2)
1.73	23 * 11 * 7	3070	0.2	2.93

Table (3) The Characteristic of Cement Mortar.

Elastic modulus(MPa)	Poisson´s Ratio	Stress (MPa)	strain
5385	0.15	18.19	0.00832

Table (4) The Geotechnical Properties for Sand and Clay Soil

Material	Clay	Sand
Modulus of elasticity(Es)	20000 kN/m^2	25000kN/m^2
Poisson ratio (ν)	0.4	0.3
Cohesion	20 kN/m^2	5 kN/m^2
Unit weight (γ),	18kN/m^3	20 kN/m^3
Angle of internal friction (f)	18deg.	35deg.

Table (5) The Pavement Data.

Material	Modulus of Elasticity (MPa)	Poisson´s Ratio	Density (Kg/m^3)
Pavement	2700	0.35	2240
Rubber	2300	0.48	1185

IV APPLIED LOAD

In this paper,a new model developed to represent the vehicle moving over the road bump for different types of bumps and vehicles.This model is checked withexperimental data [6].System represented by mass, spring and damping elements to model vehicles, bumps and shocks. Figure (3) shows the dynamic model for system and represents the parameters such as the mass (Mc), springconstant (Kc) and dampingconstant(Dc) for vehicle and the mass (Mb), spring constant(Kb) and damping constant (Dp) for road bump.The load was applied to the road bump by mass and velocity,MATLABProgram is used to get the result of load - time applied to the bump in ANSYS program show in Figure (4) [7] .

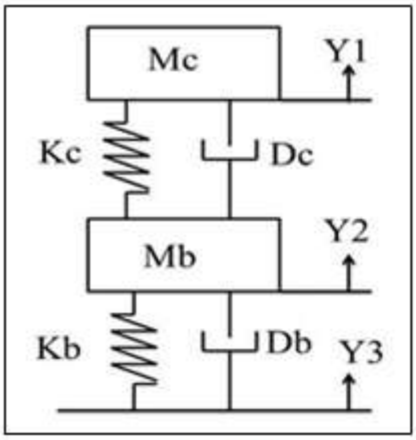


Figure (3): Dynamic

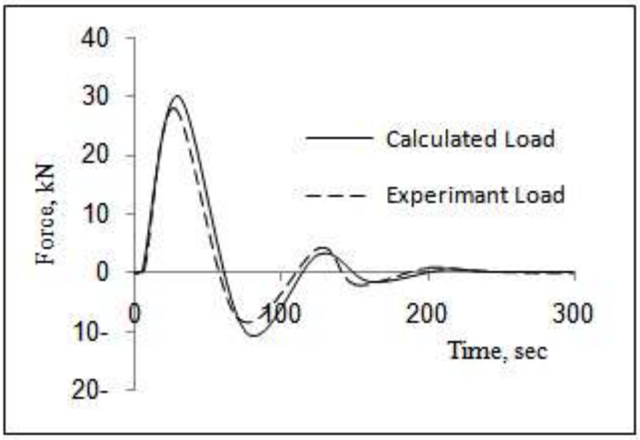
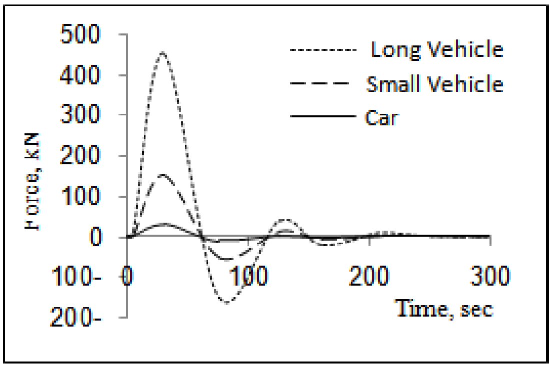


Figure (4): Comparison of Load - time for velocity 15 m/s

V. RESULT

1- Effect of vehicle type and velocity

Figure (5) shows the amount of force with time produced by vehicles passing over bumps with constant other parametric, the force increases by increasing the vehicle weight to the same speed, the increasing ratio dependson the type and weight of vehicle. Figure (6) shows the increases in force for the different vehicle velocities, the resulting force increases with the speed of the vehicle, and the increasing in force is non-linear with speed increase. And the force increasing three time when change velocity from 15 to 100 Km/sec



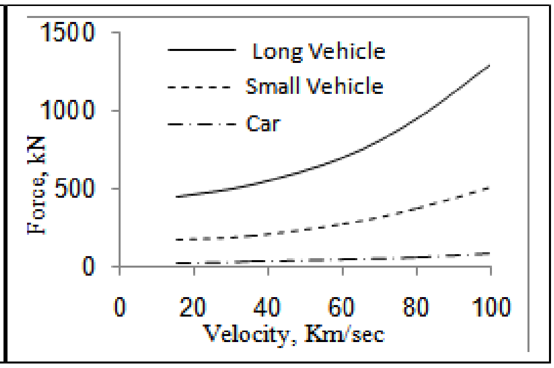
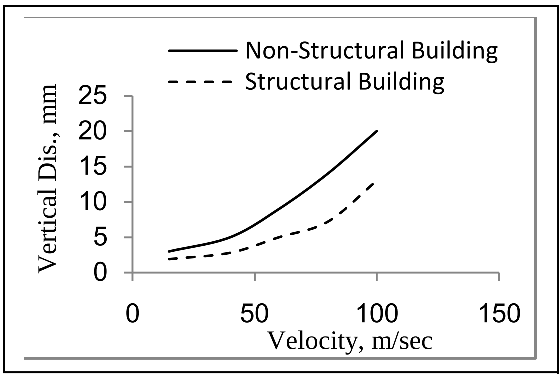


Figure (5): Effect of vehicle with time **Figure (6): Effect of vehicle Velocity.**

2- Effect of building type and floors

ANSYS analysis shows that the non-structural building is more damaged than the structural building due to many reasons such as the number of joints in the brick building, the density of the brick being less than the concrete and the cement mortar being the weakest in construction. Figure (7) shows the maximum displacement in the buildings due to vibration of a long vehicle only with constant other parametric.Figure (8) shows that the increasing in the floors number increases the rigidity and stability of the buildings and thus reduces the applied stresses.



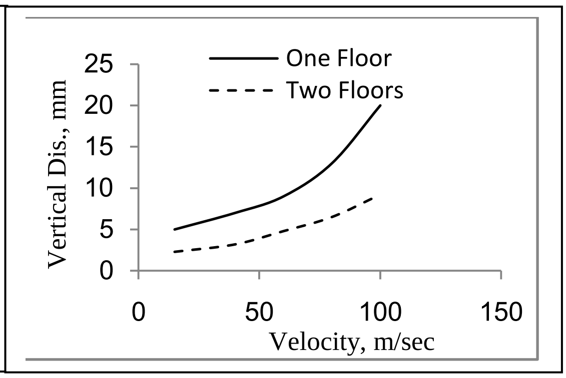


Figure (7): Effect of Building Type. **Figure (8): Effect of Building Floors.**

3- Effect of Distance between the street and Building

Figure (9) shows the effect of vibration position on building behavior with constant other parametric. It is observed that buildings near the source of vibration have more damage thanbuilding that are furtheraway, and this effect decreases when the source of the vibration moves away. The damage vanishes when the source of vibration is above 75 m away.

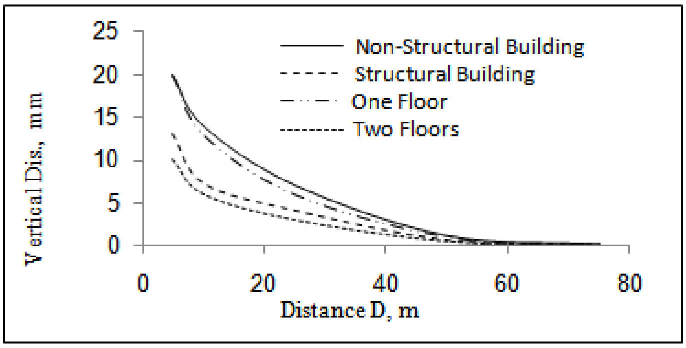


Figure (9): Effect of Distance between the street and Building

4- Effect of Bump width and material

The increase of width of the road bump reduces the force due to vehicle movement over the bump. Figure (10) shows the change in force due to changes in width from 0.5 m to 7 m with constant other parametric, where the force is reduced by 38 % when using 7 m bumps. Figure (11) shows the change in force as a result of material change of the bump with constant other parametric, where the plastic bump gives force of about (5–8)% less than the bump made of asphalt and concrete for the same width because the plastic absorbs the vibrations more than the other materials.

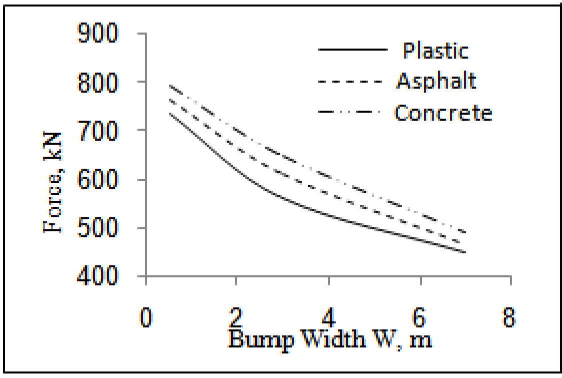


Figure (10): Effect of Bump width.

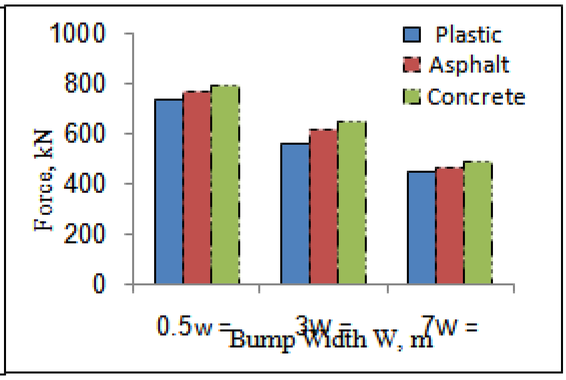


Figure (11): Effect of Bump Material.

5- Effect of soil type

Soil types effect on the structural behavior of building under the influence of vibrations due to road bumps. It is observed in Figure (12) that clay soil absorbs the vibrations more than sandy soil, and the behavior of the building based sandy soil is greater than the behavior of the same building on clay soil for the same load conditionthis increases about(15 - 23)%.

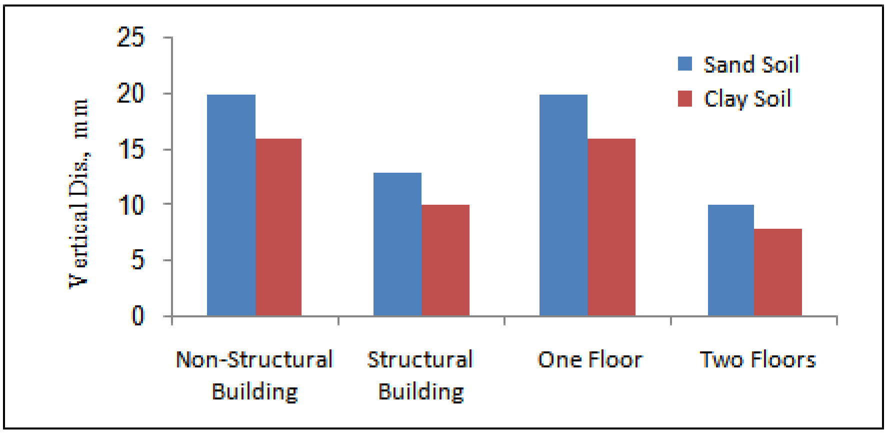


Figure (12): Effect of soil type

VI. CONCLUSIONS

The new model is used to calculate the force produced by road bumps. This model is validated well with the experimental data. The resulted show that the forces are increased by weight and speed of the vehicle with nonlinear increment ratio. The increase of building dimension and mass increases in stability due to vibration loads.Also the structural building is referred to non-structural building because reducing in joints and increasing in stiffness. The position of the vibration sources is effect on structural behavior and when the source moves away the damage becomes low. The material and dimension of road bumps is very important to reduce the vibration force, and then the rubber bump absorbs the vibration and reduces the force.Also the increase in dimension of bumps reduces the force. Soil type helps in the transmission of vibrations due to road bumps. Therefore, it is preferred to use clay soils because they allowabsorption the shock andsandy soil is able to transmit the waves through it.

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