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TO STUDY THE IMPACT OF FLOATING DEBRIS ON BRIDGE PIER

[a] Muhammad Umar Hayyat Jam*, [b] Usman Ali Naeem, [c] Faheem Butt

a: Civil Engineering Department, University of Engineering & Technology, Taxila, umerjam36@gmail.com
b: Civil Engineering Department, University of Engineering & Technology, Taxila, usman.naeem@uettaxila.edu.pk
c: Civil Engineering Department, University of Engineering & Technology, Taxila, faheem.butt@uettaxila.edu.pk
* Corresponding author: Email ID: umerjam36@gmail.com

Abstract- Storms and flooding caused significant damage to buildings and bridges. The waterborne debris created during such natural disasters will cause significant damage to many structures unless they were designed for these loads. Flood field survey findings suggested large objects such as wooden logs, cars, vessels, storage barrels, and other containers intensify the damage. For this cause, a driftwood approach was established to test tree washout, floating trees movement, and collisions with the pier. This paper addressed the findings of experimental analysis on the frameworks to measure the debris impact force and dynamic properties on pier. It also analyzed the formulas, which were defined with the experiment results in the recently released design guidelines (FEMA P-646, 2012). This resulted in impact force on bridge pier (different shapes of pier) with different debris mass and also vibrational characteristics (dynamic properties) of pier by using sensors. Moreover, different hydraulic jumps were observed while observing water surfaces in different situations.

Keywords- Experimental modeling, Flood born debris, Floods, Flow channel.

1 Introduction

Flooding is typically defined as a large volume of water overflowing outside of its normal parameters. Floods can cause extensive damage to structures, bridges, properties, and human life. Flooding is the accumulation of a large volume of fluid (typically water) from a nearby body of water that saturates the ground, which is normally dry all year. The most common causes of inland flooding are intense rains over a watershed, either a reservoir or a levee breach, or snow covers in northern areas rapidly melting [1, 2]. Understanding flood loads will thus contribute to the design and installation of flood-resistant buildings. The current construction and building guidelines pursued by [3] recommend specific methods for characterizing the debris effect load, but these are not well developed.

Flood waters in urban rivers caused by bridge obstructions by various floating debris can cause significant damage to local property, infrastructure, and members of the public, and such blockages have become more common in recent years [4-7]. These debris can include various types of vegetation, such as wooden logs, shrubs and trees, as well as urban material, including shopping trolleys, swept vehicles, and floating containers [4].

Bridge structural susceptibility in flood flows is commonly modelled. It is determined by the water depth and flow rate combined. Although the Guidelines are derived from historical flood data, their empirical investigation is extremely limited. The need to resolve the considerable number of major problems associated with such processes encourages the recent shift toward more established and simple deterministic risk assessment methodologies. Post-disaster findings have confirmed that vegetation helps to mitigate the negative consequences of natural disasters. A few notable ones from around the world are discussed briefly here. The density and thickness of the vegetation on the upstream side both contribute to the increase in backwater. A forest, depending on its configuration and thickness, can provide adequate resistance to a flood force. Experimental and numerical studies of the influences of vegetation density disclosed that increasing the aspect ratio of the vegetation limits both the water level and velocity behind the vegetation. [8]. The floating debris carried by a flood can collide with buildings and bridges, causing additional damage. Not only is vegetation important, but several factors contribute to catastrophic variations in floods. The experimental findings show that, even in sparse conditions, two rows of vegetation generated more driftwood than a single row of vegetation. More driftwood develops as the aspect ratio continues to improve. Inland forest trees can resist the stress of floating debris as well as trapped debris depending on flow velocity and Froude number [9]. Tanaka and Ogino [10] thoroughly investigated the Impulse force on locally constructed bridge pier caused by the collision of water-borne floating debris. The impact of waterborne debris on bridge piers in the presence and absence of vegetation on structural buildings is investigated in this paper.

During flood events, debris makes contact with bridge piers in the flood water's path, causing an impact, hydrostatic and hydrodynamic loading on bridge pier. Floodwater debris strikes residential or other structures in the floodplain. The above implications slow down the debris and apply force to the bridge pier. The intensity of the force can indeed be large enough to cause significant, if not disastrous, structural damage. The aim of this study is to evaluate impact forces on bridge pier due to floating debris depending on mass and velocity of prototype floating woody debris by experimental procedure as well as numerical analysis.

2 Experimental Procedures

2.1 Forces On Bridge Pier Due To Flood Born Debris.

The structural fragility of bridge pier is determined by both demand (loading) and structural sustainability (capability). This study focuses on the structural loading caused by the flood. During catastrophic disasters, the advancement of floodplains in high-risk areas can be subject to a variety of forces, including impact forces.

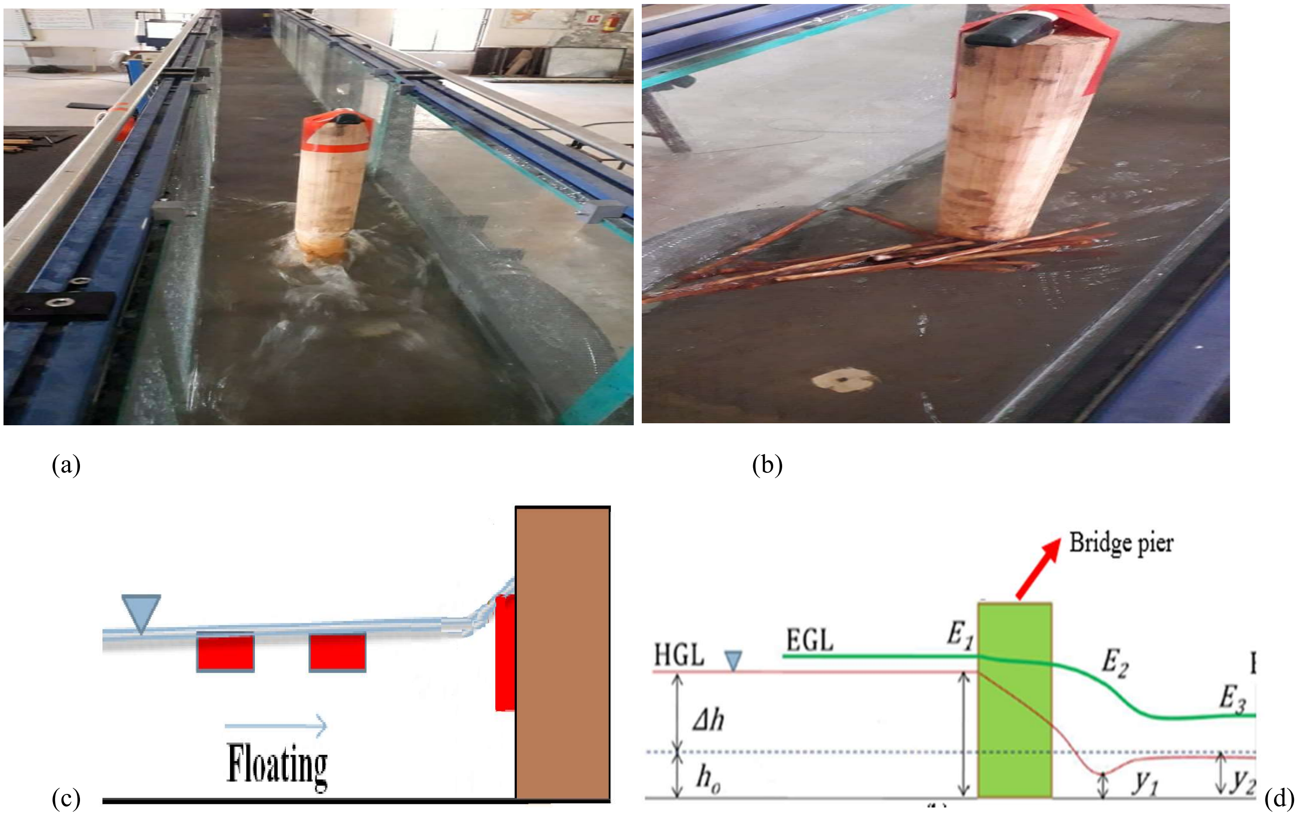

Figure 1: Schematic view of (a) flow channel with pier (b) Debris impact with pier (c-d) Flow behavior and difference of different parameters in the presence of floating debris with bridge pier

2.2 Impact force

FEMA P-55(2011) suggested an equation to determine impact force which is

$$F_i = WVC_D C_{str} C_B \qquad (1)$$

Wherein F_i is the impact force, W is the debris weight, V is the debris velocity, $C_D C_{str}$ and C_B are the depth, building structure, and blockage coefficients, respectively. Based on the flow depth the depth and blocking coefficients range from 0-1. Meanwhile, C_{str} is based on the form of structure, the direction, the natural phase, and the period of the impact. The coefficients in Eq.1 are obtained from laboratory results as well as engineering conclusions.

The FEMA P-646 (2012) [7] introduced the formula to determine debris impact forces that differed from the previous version, and the following is:

$$F_i = 1.3\, u_{max}\sqrt{km_d(1+c)} \qquad (2)$$

For which, u_{max} refers to the maximum velocity of flow close to the structure. The velocity of the moving debris is believed to be equal to the velocity of flowing water. k,m_d, c refers to the combined rigidity of the impacted structures, the mass of the debris, and the hydrodynamic mass coefficient respectively. As per FEMA P-646 [11] for wooden debris, for debris that flows parallel to the flow direction, $c = 0$, for debris with a transverse orientation towards flow direction $c = 1$, Whereas for debris such as 20-ft and 40-ft cargo ships, $c = 3$ and $c = 2$ respectively.

2.3 Hydrostatic force.

The horizontal hydrostatic force is extracted from the change in water level on wall upstream and downstream sides. It is given per unit length by:
Where ρ and g are the density of water and the gravitational acceleration respectively while as h_us and h_ds are referred to as depth of water upstream and downstream of the wall.

2.4 Hydrodynamic Force.

Hydrodynamic force is resulted from a composite of inertia and drag, while as it depends on both kinematics and dynamics of the flow and characteristics of structure respectively. The following concise expression is, in general, followed for the Hydrodynamic force per unit length is.

$$F = C_d.\rho.g.h.u^2 \qquad (3)$$

Where C_d is the drag coefficient, h and u are the depth of water near wall and velocity component orthogonal to the object respectively.

3 Research Methodology

In a glass-sided water flume (constant bed slope 1/500) that is 10 m long, 0.30 m wide, and 0.34 m high at the University of Engineering and Technology Taxila, laboratory tests were performed under various conditions. The schematic figure of the water channel is shown in Fig.1 (c-d). A small scale (1/45) of a bridge pier was designed to test the relationship of the bore structure and the effect of debris on the structure. This bridge pier has a height of 0.55 m, a width of 0.03 m, and a length of 0.10 m and provided an equal building height of 675 cm, a length of 457 cm, and a real building width of 457 cm. As per the horizontal impact of debris, Eq.2 was used to measure the impact forces on the bridge pier. A high-speed digital camera was used to monitor the behavior of the structure model and the velocity, direction, and effect of debris flow with the bridge pier. To study the change of vibrational characteristics (dynamic properties) of bridge pier by using sensors.

Different pieces of wooden planks collide in the staggered arrangement shown in Fig. 1(b) each with various sizes, diameter, and weights, was used to measure the effect caused by the wood debris. Moreover, the wooden pier model in the open channel is shown in Fig.1 (a). The debris weight was then selected to fit target weights of 0.42 g, 0.43 g, 0.48 g, and 0.49 g to reflect the debris scale of 1/45. The complete detail of debris used in the present experimental work is given in shown in Fig.1 (d) and table 2.

Table 2: Debris used in the present work are;

Debris Type	Length (mm)	Diameter (mm)	Weight (gm)
D1	97	12.65	14.3
D2	153	18.2	17.6
D3	266	19.34	18.24
D4	255	18.7	29.55

4 Results

4.1 Debris Impact Forces.

Fig. 2 represents the experimentally derived values on the composition of the debris. They were determined using the formulas given in the design guidelines. FEMA P-646 (Eq. 2) is to investigate the impact force (Fig.2) of all debris given in table 2. The Forces displayed in Fig. 2 are based on the velocity of the debris that is measured experimentally. For wooden log debris, FEMA P-646 [11] suggested C=1 and $k=2.4\times10^{6}$.

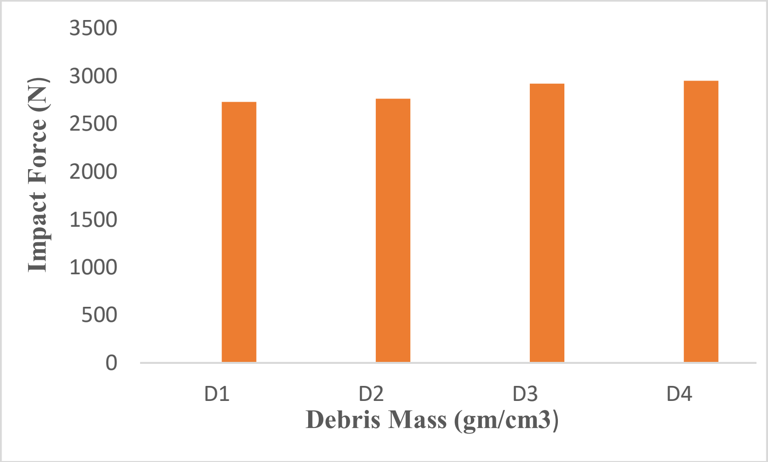

Figure 2: Impact force of different debris mass on bridge pier

The impact force was related directly to the mass of debris, as shown in Fig. 2. The highest value of impact force was noticed for D4, while the lowest value was noted for D1. Similarly, in terms of impact force, which is dependent on u/s and d/s water head, D3 had the highest value due to its longer length (26.6 cm) when compared to other debris (D1, D2, and D4). D2 debris had a lower value due to its shorter length (9.7 cm) and lower diameter value (1 cm). The lower hydrodynamic magnitude reflected the lower values of water accumulation upstream of the pier. Because the dynamic force was affected by flow velocity, the D2 type of debris had the highest value in comparison to the D3 type of debris, which had the lowest value. Because the flow velocity and debris velocity were the same, the experiment confirmed that higher flow depth due to longer length reflected the lower velocity shown in Fig. 2.

4.2 Use of Software.

There are number of softwares available which can mimic the process involved in research work and can produce the possible results. One of such type of software is MATLAB. The data of vibrations of piers was collected by using sensor, when debris of different masses collided with piers of different shapes. The vibrational characteristics (dynamic properties) of bridge pier was obtained by using MATLAB software and it eased the process of paper writing.

As by adopting the above practices all dynamic properties of bridge pier of a research paper can be written and together compiled to form complete research ready for Peer review.

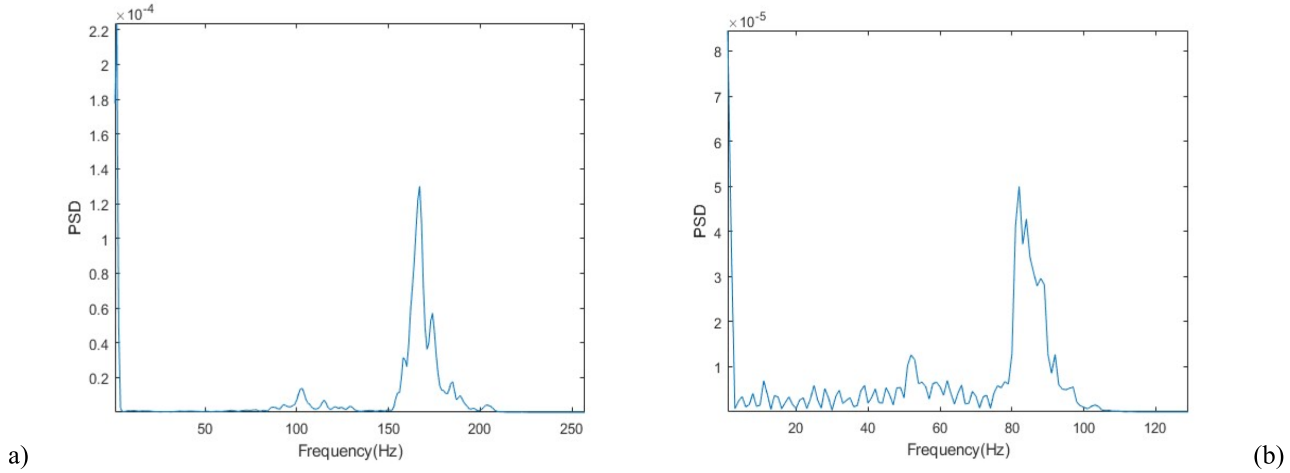

Figure 3: (a) Vibrational characteristics of original pier (b) Vibrational characteristics of scrapped pier

5 Conclusion

Following conclusions can be withdrawn from the conducted study:

1. The analysis of stability of structures in flood-prone areas is a key problem in assessing flood-induced risks, particularly given the high correlation of life loss throughout these tragic events.
2. The highest value of impact force was observed for D4 (2950.6 N) while the minimum value for the debris D1 (2731.6 N).
3. During the analysis, it was found that the FEMA P-646 equation provided a better and more accurate calculation of the impact forces.
4. It was observed that dynamic properties of pier has more stiffness at dominant frequency (170Hz) when pier in original shape and less stiffness at frequency (85Hz) when pier is scrapped.

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