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Blast Load Mitigation of Concrete Bridge Circular Pier by external Strengthening using CFRP Laminates and CNT Rubber Lining

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Abstract : In recent years, due to the increased terrorist attacks on various important civil structures the need of analysis, design, and protection against blast is necessary. These attacks are carried out using high explosive devices, resulting in destructive effects on survivability of structure and occupants. One of the most important examples of such incident is September 11, 2001 attack at World Trade Centre, New York, U.S., which led to change in focus of more research emphasis towards structure safety against such manmade devastating attacks. This blast-induced impulsive load needs assessment to establish and arrive at an agreeable threat level against which mitigation/protection measures need to be implemented.

This study aims to investigate the effect of blast load on various materials used for external strengthening of a circular pier of concrete bridge. In this paper a circular bridge pier of 400mm with 4m is used with three different conditions. CFRP laminates are wrapped around the circular pier in first case, CNT rubber lining (composite of LaRC-SI polymer and 1% fraction of SWNT) is used in second case and in the third case conventional concrete is replaced by CNT reinforced concrete. The blast load is applying at mid-height of the pier with 100kg of TNT with varying standoff distance. The results are obtained analytically using LS DYNA software. Results indicate that all three materials are effective in reducing the lateral deflection of pier.

Index Terms - Blast Load, Mitigation, CFRP laminates, CNT, TNT.

I. Introduction

Recent years have seen an increase in terrorist strikes on various major civil structures. This has generated the need to study, analyze, and design against the blast protection. These attacks are made with high-explosive equipment, which have devastating consequences on the structures and people' survivability. September 11, 2001 attack on the World Trade Center in New York is the well-known example of such attack incidents. This attack has prompted a shift in study focus to structure safety in the face of such manmade deadly strikes. This blast-induced impulsive load must be assessed in order to determine and agree on a threat level against which mitigation/protection measures can be taken. The permissible damage to the structure is determined and designed based on this threat level.

There are three major categories of these explosive sources.

1. Physical explosion
2. Nuclear explosion
3. Chemical explosion

Physical explosions can occur when a gas cylinder fails, a volcano erupts, or two liquids of different temperatures or a hot particulate particle is mixed with a cool liquid. During the nuclear explosion, the redistribution of protons and neutrons inside the interacting nuclei releases energy from the production of distinct atomic nuclei. A chemical explosion, on the other hand, is caused by the rapid oxidation of fuel elements (carbon and hydrogen atoms) within the explosive combination. Chemical explosions are considered to be the prime source of terrorist attacks all around the world. The bulk of explosives are condensed, which means they are solid or liquid at the same time.

Past research on the reaction of structures to impact burdens has concentrated basically on structures. Authentic information appears, notwithstanding, that assaults on transportation resources have expanded as of late and that scaffolds are the most every now and again assaulted transportation structure. Interstate foundation can be an appealing fear-based oppressor target in light of the fact that the departure of a basic part, for example, a scaffold, can have extraordinary monetary and mental effects, which are viewed as regular psychological militant destinations Bridges present one-of-a-kind difficulties on the grounds that these structures must stay available to the motoring open. Therefore, satisfactory standoff can't frequently be accomplished to secure basic extension individuals, and many scaffold segments are stacked legitimately instead of in a roundabout way through an exterior framework. The cost of these mitigation solutions is lower than the cost of strengthening strategies. Only where there is enough space can the standoff distance be extended; however, in a metropolitan context, it is often impossible to implement techniques that demand space. The sacrificial blast wall is a preferable answer in these cases and can be employed or designed to protect against an explosive-induced threat. Instead of a Sacrifice wall, another layer of CFRP laminate and CNT rubber is used, and the effect is investigated.

Strengthening members and protection/mitigation strategies are the two basic categories of strategies for protecting structures against blasts. Because the blast pressure decays rapidly and even a short distance is relevant, the effect can be decreased primarily by increasing the standoff distance from the hazard. The cost of these mitigation solutions is lower than the cost of strengthening strategies. Only where there is enough space can the standoff distance be extended; however, in a metropolitan context, it is often impossible to implement techniques that demand space. The sacrificial blast wall is a superior answer in these cases and can be used or created to protect against an explosive-induced threat. In comparison to conventional materials, the numerous lightweight materials utilized for this purpose add to the blast resistance. Instead of employing a Sacrifice wall, another layer of CFRP laminate and CNT rubber is added around the Pier for external reinforcement, and the CNT reinforced concrete Pier is analytically analyzed and its effect studied.

In this research paper charge weight and charge centre distance from structure has been determined. This paper also determining CFRP laminate and CNT Natural Rubber lining specifications.

2. MATERIAL AND METHODOLOGY

The majority of structural materials (steel, concrete, glass, etc.) have been found to have no effect on the reflection of blast overpressure. Low peak reflected overpressure is achieved by using lightweight energy-absorbing materials. These lightweight advanced materials, including as foams (metal and polymeric foams), have shown great potential for use as sacrificial blast walls in blast mitigation. In comparison to a rigid protection system, lightweight flexible type members reduce energy transfer to the parent structure, assisting in blast mitigation

3. RESULTS AND DISCUSSION

Here three different cases are considered. Circular pier of bridge is considered with 400mm diameter and height 3.75m is used with one edge fixed and another end is pinned. In Case I conventional concrete is considered and 100kg TNT charge weight is applied. In Case II CFRP laminates are wrapped around the Pier of case I. In case III CNT reinforced polymer is assumed to be wrapped as lining around the pier. In case IV the conventional concrete is replaced with CNT concrete and first with same steel content another pier is designed and similar pier with another diameter is compared and most effective is taken for further discussion. The boundary conditions are pinned at top end and fixed at bottom end. The stresses generated due to applied blast load is shown in table 1. The maximum principal stress decreases with all the three materials. But most decrease is due to CNT concrete and after that CFRP laminates and then CNT lining. Similar results are observed with minimum principal stresses. Reduction is maximum with CNT concrete but CNT lining has less reduction as compared with CFRP laminates for minimum principal stresses.

Table 1. Maximum and Minimum stresses generated in Pier

	Conventional	CFRP Laminar	CNT lining	CNT Concrete
Maximum Principal Stress	5.89	5.53	5.7	4.46
Minimum Principal Stress	5.71	5.46	2.93	2.02

The shear stress and bending moment generated in the beam element used for reinforcement is shown in table 2.

Table 2 Shear resultants in the beam elements used for reinforcement

	Conventional	Part	CFRP Laminar	Part	CNT lining	Part	CNT Concrete	Part
s- shear resultant	12550	2	9397.2	2	10134	2	1745.4	2
T-shear resultants	5294.9	1	5071.6	1	5257	2	1630	1
s- bending moment	47686	2	21.608	2	16119	2	8108.4	1
t-bending moment	53458	2	28532	2	22919	2	14998	2

Table 2 shows different shear and bending moment values along with the part numbers. Here Part 1 represents shear reinforcement and Part 2 represents longitudinal reinforcement.

The stresses generated in x y and z direction of the piers are shown in table 3.

Table 3 Stresses generated in different directions of the pier

	Conventional	CFRP Laminar	CNT lining	CNT Concrete
X-STRESS	4.34	3.56	5.47	3.58
Y-STRESS	4.68	5.01	4.82	3.72
Z-STRESS	5.08	4.53	4.89	4.42

The table 6.3 shows stresses in different directions and all the models are made with same coordinates and load is also applies on the same coordinate. In conventional concrete the maximum stress is in Z- direction i.e., along length. Similar results are observed with CNT concrete with reduced stress values. But in case of CFRP laminates and CNT lining the maximum are along Y-direction and X-direction. The Lateral Displacement observed in Pier with single blast load source and varying standoff distance is shown in table 6.4. The displacement is for 60 msec and the peak lateral displacement and permanent lateral displacement is noted which is shown in table 12. Here the peak displacement as well as permanent displacement decreases with increased standoff distance. If the meshing is fine in modelling the displacement can be further decreased. Due to the various material properties of the different materials, there is a considerable decrease in peal and lateral displacement after application of different materials. Peak displacement is where CFRP laminates show the most reduction. However, in terms of permanent displacement, CNT lining produces somewhat improved result as the standoff displacement is increased. Figure 1 depicts a comparison of various situations and their displacement behaviour over time.

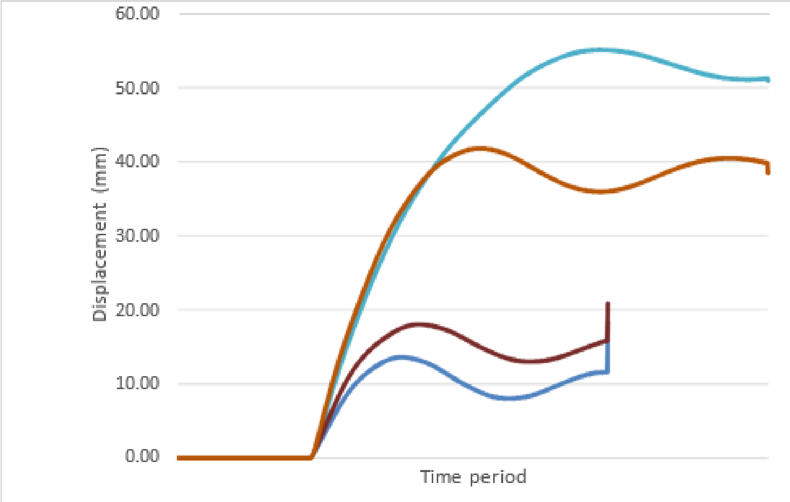

Figure 6.1 Displacement Vs Time graph of Circular Pier, with CFRP Laminates and CNT polymer array

The maximum principal stress decreases with all the three materials. But most decrease is due to CNT concrete and after that CFRP laminates and then CNT lining. Similar results are observed with minimum principal stresses. Reduction is maximum with CNT concrete but CNT lining has less reduction as compared with CFRP laminates for minimum principle stresses. The stresses in different directions and all the models are made with same coordinates and load is also applies on the same coordinate. In conventional concrete the maximum stress is in Z- direction i.e., along length. Similar results are observed with CNT concrete with reduced stress values. But in case of CFRP laminates and CNT lining the maximum are along Y-direction and X-direction. The maximum decrease is observed in CFRP laminates in peak displacement. But of permanent displacement is to be considered CNT lining shows somewhat better results.
Here the maximum displacement is observed in the circular pier of 55.055mm but when CFRP laminate is wrapped around the pier the displacement is reduced to 18.2mm (66.9 % reduction). When CNT polymer array lining is provided around the pier the displacement observed is 20.84mm (62.14 % reduction) and when concrete is replaced with CNT concrete observed displacement is 38.4mm (30.24 % reduction).

Table 4 Lateral Displacement of Piers with varying standoff distance

	Conventional		CFRP Laminar		CNT lining		CNT concrete	
	Peak movement	Permanent movement	Peak movement	Permanent movement		Peak movement	Permanent movement	Peak movement
1m	55.1	51.055	13.6	18.4 2	18.1	20.84	36.4	34.4
2m	18.73	8.9	3.6	2.7	5.18	0.9	14.6	13.7
3m	11.35	10.5	1.6	3.81	2.25	2.3	9.52	12.4

4. CONCLUSION

Research paper deals with the effect of blast load on circular pier, Circular Pier withCFRP laminates and CNT polymer array. Graph 5 shows displacement vs. Time Graphof the three models of Circular Pier, Circular Pier with CFRP laminates and Circular Pier with CNT polymer array. Based on the research, comparison of the four cases is been done and it results to be an effective solution if any of the cases are used for mitigate purpose analytically.

1. The maximum displacement is observed in the circular pier of 55.055mm but when CFRP laminate is wrapped around the pier the displacement is reduced to18.2mm (66.9 % reduction).
2. When CNT polymer array lining is provided around the pier the displacement observed is 20.84mm (62.14 % reduction for 0.1% CNT content))
3. When concrete is replaced with CNT concrete observed displacement is 39.39mm (28.45 % reduction for 0.1% CNT content).
4. With the increase in standoff distance the lateral displacement is reducing. Morewill be the standoff distance less will be the damage.
5. When the standoff distance is 1m from the charge weight CFRP laminate showsless displacement in comparison with the other two materials.

6. When the standoff distance is 2m from the charge weight CNT lining seems to be more effective in terms of permanent displacement.
7. With the increased diameter of Pier Lateral displacement is reduced.

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