Comparison of concrete filled CFRP tubes and Steel tubes under impact loading

Bency K Thampy[1], Asst. Prof Manasa M S

1MTech. Student, Dept. of Civil Engineering, Holy Kings College of Engineering and Technology, Kerala, India
2 Asst. Professor, Dept. of Civil Engineering, Holy Kings college of Engineering and Technology, Kerala, India

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Abstract - *An impact is a high force or shock applied over a short time period when two or more bodies collide. Ordinary concrete, which is one of the most widely used construction materials, is weak under such extreme loadings because of its poor energy absorption capacity and brittle nature. Large mass or velocity impacts can cause extensive structural damage or collapse. If the member is a load bearing column, its destruction may lead to a catastrophic progressive collapse of the structure. Carbon Fiber have the properties like High Strength to weight ratio, Rigidity, Corrosion resistance, Electrical Conductivity, Fatigue Resistance, Good tensile strength but Brittle, Fire Resistance etc. Reinforcing concrete with Steel fibres results in durable concrete with a high flexural and fatigue flexural strength which improved abrasion, spalling and impact resistance. A parametric study was conducted using the verified models to investigate the effects of thickness and hammer velocity on the response of CFRP and steel tubes under impact loading. To compare the impact resistance of steel as well as CFRP, which is durable under impact loading. And to suggest an optimum thickness for the safe design.*

Key Words: **Impact, Steel tubes, CFRP, Hammer velocity, Deflection**

1.INTRODUCTION

An impact is a high force or shock applied over a short time period when two or more bodies collide. Such a force or acceleration usually has a greater effect than a lower force applied over a proportionally longer period. The effect depends critically on the relative velocity of the bodies to one another. Different materials can behave in quite different ways in impact when compared with static loading conditions. Ductile materials like steel tend to become more brittle at high loading rates, and spalling may occur on the reverse side to the impact if penetration doesn't occur. The way in which the kinetic energy is distributed through the section is also important in determining its response.
Ordinary concrete, which is one of the most widely used construction materials, is weak under such extreme loadings because of its poor energy absorption capacity and brittle nature. Large mass or velocity impacts can cause extensive structural damage or collapse. They can be caused by wind generated missiles, vehicle collisions, or weapons, among other things. The analysis and design against these impacts is complicated by the resulting dynamic inertial loads and the effect of the high strain rates on the material properties. Therefore the improvement in impact resistance or dynamic analysis and design procedures has great importance to structural engineering.

The term impact refers to a dynamic effect of a load which is applied suddenly. The applied load can be considered to be of an instantaneous nature. A common type of structural analysis problem results from an impact load. The impact could be caused by a weight falling on the design object or possibly from the design object falling and striking a hard surface. At one time or another most engineers run into cases of impact loading. The general problem of impact is extremely complex. A common case of impact is vehicle collision with a traffic barrier involves large displacements, material non-linearity, elastic and plastic instability, post-buckling strength, coulomb friction and material behavior under high strain rates. Finite element methods can provide an 'exact' solution, but reasonable and useful engineering estimates are possible simply from considerations of a few first principles with some simplifying assumptions. The effect of an impact force on structure depends on the shape, mass, and velocity of the impacting body; the contact area; the structure's dynamic response; and the material type, etc. A significant analysis effort is required to evaluate the behavior of a structure under impact loading. To simplify the design, a methodology has been developed using an equivalent static load for a framed structure under impact load.

1.1 Scope and objective

The main objectives of the report are as follows:

• To verify and compare the dynamic behavior of concrete-filled CFRP tubes as well as steel tube under impact using ANSYS-Autodyn-17 platform.
• Performance analysis by conducting a parametric study on;

- Effect of thickness
- And hammer velocity

• To provide simple design recommendations based on the numerical results.

The scope of the study;

• Due to the time and resource constraints study is limited to numerical analysis only.

• A number of strengthening materials are available but the study is limited to CFRP and Steel.

• Considering only two parameters, such as
- Thickness
- Hammer velocity

2. MATERIAL MODEL

Table -1: ANSYS AUTODYN input parameters for Steel, Concrete and CFRP tube Material models

Material	Material model	Parameters	Value
Steel 4340	Johnson Cook Strength model	Yield stess (kPa) Hardening constant Hardening exponent	7.92×10^5 5.1×10^5 0.26
Steel 1006	Johnson Cook Strength model	Yield stess (kPa) Hardening constant Hardening exponent	3.5×10^5 2.75×10^5 0.36
Concrete	RHT concrete	Compressive strength (kPa) Shear modulus (kPa)	3.5×10^4 1.67×10^7
CFRP tube	Orthotropic elasticity	Young's modulus (MPa) Poisson's ratio Shear modulus (MPa)	91820 0.3 3000

The material properties used for analysis in software ANSYS are given in the tables. The details of steel used and the properties of reinforced concrete is given in the table. The concrete used for the analysis is RHT concrete and the steel used is Johnson Cook Strength model. Steel 4340 and steel 1006 are used. Concrete M35 is used for the analysis.

Table -2: Material properties of reinforced cross section

Parameters	Value	Unit
Density	2500	Kg/m^3
Specific heat	654	J/kg
Compressive strength	35000	kPa
Tensile strength, ft/fc	0.1	
Shear strength, fs/fc	0.18	
Shear modulus	16700	MPa

3. RESULTS AND DISCUSSIONS

The total deformation obtained for controlled structure for all the velocities are calculated. And it is clear that the deformation will increases when the impact velocity increases.

Table -3: Total deformation obtained for all the velocities

Velocity (m/s)	Total deformation (mm)
1.22	5.035
1.32	7.8133
1.35	7.878
1.56	15.603

So the maximum deformation is obtained for 1.56m/s velocity impact which is 15.603 mm. And the minimum value is 5.035 mm for the impact velocity 1.22 m/s. The deformation curve is given in figure below. The impact is given using a hammer of weight 561kg and the velocities used for the analysis are 1.22m/s, 1.32m/s, 1.35m/s and 1.56m/s. So from the table it is clear that total deformation decreases as the velocity of impact increases. It is clearly shown in the deflection curve provided below.

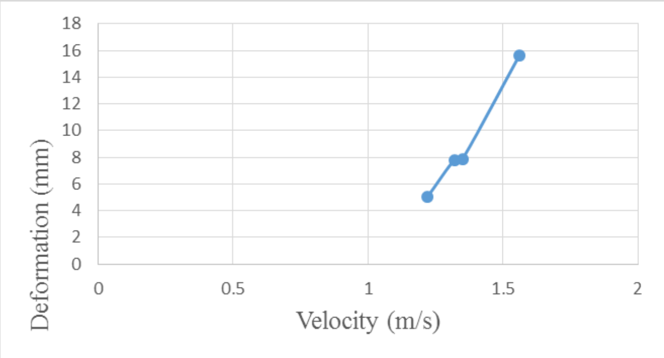

Chart -1: Deformation Curve

Table -4: Total deformation for Steel column

Thickness (mm)	Velocity (m/s)	Total deformation (mm)
6	1.22	1.3639
	1.32	1.4768
	1.35	1.5108
	1.56	1.7501
8	1.22	1.3993
	1.32	1.6358
	1.35	1.6429
	1.56	1.6963
10	1.22	1.2311
	1.32	1.6087
	1.35	1.6152
	1.56	1.6693

Table -5: Total deformation for CFRP column

Thickness (mm)	Velocity (m/s)	Total deformation (mm)
6	1.22	1.6501
	1.32	1.7899
	1.35	1.8322
	1.56	2.1336

8	1.22	0.17076
	1.32	0.15801
	1.35	0.17461
	1.56	0.20275
10	1.22	0.15152
	1.32	0.16383
	1.35	0.16754
	1.56	0.19448

The total deformation obtained for the velocities 1.22m/s, 1.32m/s, 1.35m/s and 1.56m/s by varying thickness as 6mm, 8mm and 10mm are given in the table. From the table it is clear that the value obtained for total deformation for maximum thickness of steel will be approximately equal to 6mm thickened CFRP tube.

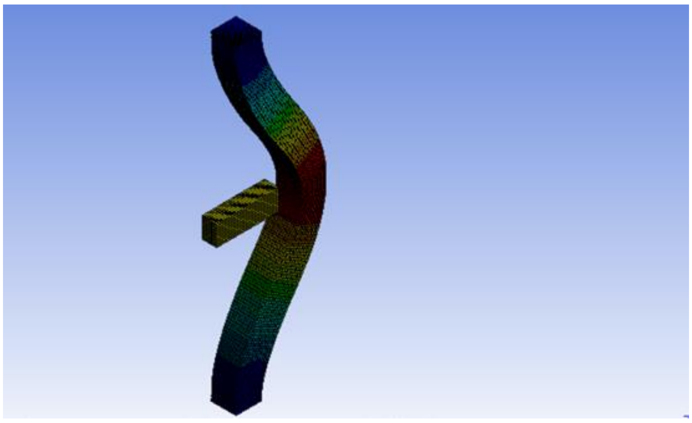

Fig -1: Deflected column

4. CONCLUSIONS

The models of the column with steel, CFRP and without steel and CFRP is modelled and analysed for various velocities 1.22, 1.32, 1.35, 1.56 m/s. The steel and CFRP are provided at a thickness of 6mm, 8mm and 10mm. From the analysis it is clear that when velocity increases the total deformation will also increases. But the CFRP tube will have less deformation when compared with steel and controlled structure. So it can be concluded that CFRP can with stand more impact than the steel.

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