ASSESSMENT OF RC BEAM USING TRUSS PATTERN SHEAR REINFORCEMENT

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ABSTRACT

For designing the beam, the traditional reinforcing configuration of the main bar & stirrup is extensively utilized. We rarely perceive any alternative design. We know that shear failure is more brittle and sudden than flexural failure so RC members' shear capacity should be more than the flexural capacity. As a result, in our research, we are attempting to develop a different shear reinforcement pattern that can endure shear more efficiently than the traditional one. So, we proposed three-beam designs based on the idea of three truss patterns: Pratt, Howe, and Warren truss. We're adopting the solid steel square bar instead of normal rebar to compare the strength of a typical rebar beam to our suggested steel beams. Furthermore, if the same amount of load is applied to the traditional beam and the truss pattern steel beams, we want to build a theoretical concept of who will withstand greater load from the conventional beam and the other three truss pattern steel beams. We used ABAQUS software to analyze with an equivalent amount of load. Various graphs, such as load vs displacement curves, total energy vs time curves, and stress-strain curves, show that the conventional RC beam fails at 0.24kN load, which is far earlier than one of our proposed Howe Truss Pattern Steel Beams, which fails at 7kN load. Furthermore, because the ultimate load of the Howe truss pattern steel beam is greater than all other beams, it also shows that this beam requires more energy to fail, nearly 4.31mJ, than all other beams. Besides that, our conventional beam can withstand only 2Mpa stress, whereas our designed Howe Truss Pattern Steel Beam can withstand almost 13Mpa stress, which is more satisfactory than the conventional beam. As a result of our analysis, we can conclude that our suggested Howe Truss Pattern Steel Beam from all the beams can serve as a viable alternative to our current beam reinforcing design.

Keywords: *ABAQUS, FE analysis, shear reinforcement, truss pattern, shear failure.*

1. INTRODUCTION

The Reinforced concrete (RC) beams are structural components that support external loads. Bending moments, shear forces, and, in some cases, torsion are produced by the loads. Furthermore, while concrete is extremely strong in compression, it is quite weak in tension. As a consequence, steel reinforcing was introduced to RC beams to withstand tensile stress. The two most typical failure modes in RC members are shear and flexure. Structures become brittle or ductile as a result of these modes. Because shear failure is brittle and sudden, the shear capacity of RC members should be greater than the flexural capacity, so that a beam fails first for flexural failure(Demir et al., 2016). Stirrups are frequently used to evaluate the shear performance of RC structural components, and stirrup spacing is especially maintained for this purpose.

Taking everything into account, we're looking for a viable substitute to our standard stirrups configuration. In this study, we proposed three distinct truss models which are Warren Truss Pattern Beam [Figure 1.1], Pratt Truss Pattern Beam [Figure 1.2], and Howe Truss Pattern Beam [Figure 1.3] to evaluate which model can aid with the most shear. To do so, we will compare our suggested models to the conventional model [Figure 1.4] while applying the same amount of load. We used ABAQUS for this analysis. In our research, all of our beam models had the same dimensions: length=2820mm, width=290mm, and thickness=290mm.

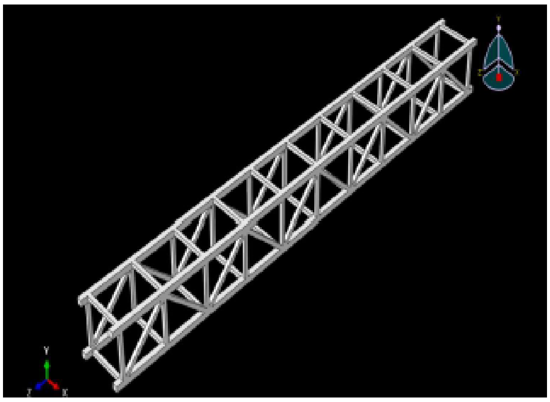

Figure 1.1: Warren truss pattern beam

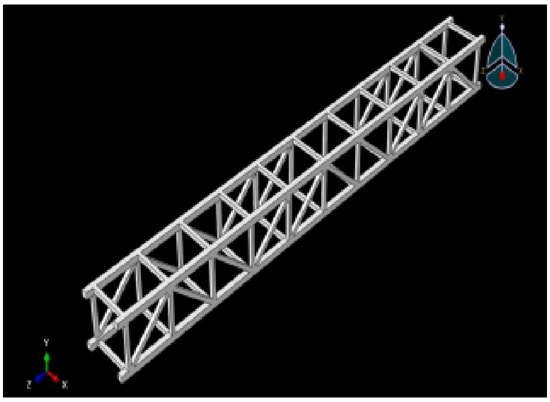

Figure 1.2: Pratt truss pattern beam

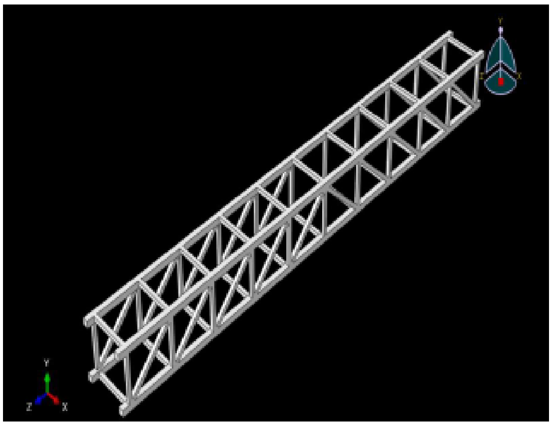

Figure 1.3: Howe truss pattern beam

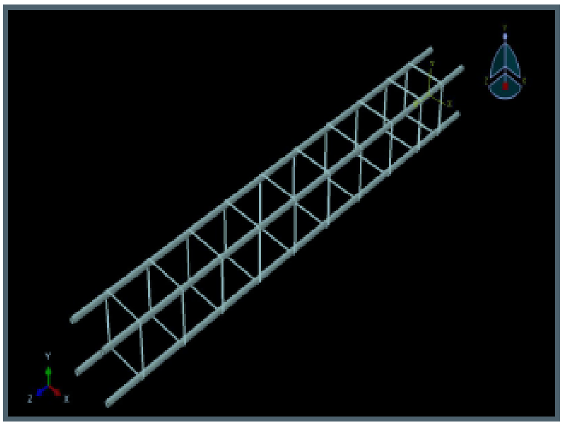

Figure 1.4: Conventional beam

Research showed that improvement in stirrup yielding strength is much more efficacious than improvements in concrete compressive strength in strengthening the shear strength of deteriorated reinforced concrete beams. In terms of the three types of stirrups, the shear strength of deformed HRB-335 beams is the least susceptible to stirrup corrosion, followed by smooth HPB-235 beams and deformed HRB-400 beams. The influence of various stirrups on shear strength is influenced by the quality of stirrup corrosion and the shear span-to-depth ratio of the beam (Lu et al., 2019). Also, another study shows, Diagonal shear reinforcement (DSR) is a shear reinforcement arrangement that can be used to improve the shear capacity of a beam. When DSR is used, the shear and ductility performance of RC beams is substantially enhanced. Moreover, as the diameter and yield strength of

DSR rise, the shear capacity increases, and the failure mode switches from shear to flexure. As a corollary, the DSR reinforcement design provides more ductile behavior for shear critical RC beams(Demir et al., 2016). Hybrid Steel Trussed Concrete Beams (HSTCBs) is an architectural type of composite beam manufactured out of prefabricated steel trusses embedded into an in-situ concrete matrix. They are generally implemented as an efficient structural approach to lightweight urbanization. The shear resistance of the HSTCB is composed of concrete and shear reinforcements, with the steel truss's diagonal rebar acting as stirrups, as they do in R.C. beams. The squeezed concrete strut's crisis results in a brittle shear fracture. In any of those scenarios when the mechanical properties of the concrete were sufficient to allow the strut to break, the steel components were adequate to provide ductility to the structure even before maximum load was attained (Campione et al., 2016). The strut and tie models, introduced by Ritter (1899) and Mörsch (1927), are utilized in the shear design of reinforced concrete beams. They found that tensile and compressive struts may be used to idealize the complex inner states of stresses. Spatial finite element models with concrete solids and embedded truss elements – representing stirrups and longitudinal bars – are particularly well suited for numerically simulating the load-bearing behavior of RC beams (Birtel & Mark, 2006).

2. METHODOLOGY

This section goes through a method for evaluating reinforced concrete structures. The Finite Element Method (FEM) is used to get essential information about the structural model to investigate it. To assess the structural model using FEM, we adopted the ABAQUS program. ABAQUS is a strong design and analysis software application that is currently available. ABAQUS analysis has been conducted into various phases which are described below.

2.1 Part

At first, we need to define a normal beam and three truss pattern beams. We used solid and 3D shapes for all types of beams.

Table 1: Beam dimensions

Conventional Beam	Truss Pattern Beam
Length-2820mm	Length-2820mm
Thickness-290mm	Thickness-290mm
Width-290mm	Width-290mm

2.2 Property

In this step, we entered the Steel and Concrete properties, which are shown below.

Table 2: Steel material properties

Young Modulus	Poisson’s Ratio	Yield Stress	Density
2.00E+05 N/mm^2	0.3	420 N/mm^2	0.7 N/mm^3

Table 3: Concrete material properties

Density	f′c	E_c	Poisson’s Ratio	Young Modulus
2.4e-5 N/mm^3	27.6 N/mm^2	24855.6 N/mm^2	0.2	1.5e-5 N/mm^2

2.3 Assembly

First, select the newly created instance before going to the assembly step. Then select the stirrup part. Again, when going to create an instance, select the rebar part. Then select the translated instance. The stirrups are placed one after the other at a certain distance, and then each joining pair is attached to the partition face. Then select the instance again and add the concrete part, repeating the whole process in the same way. And then it eventually took the shape of a rectangular beam, as illustrated below.

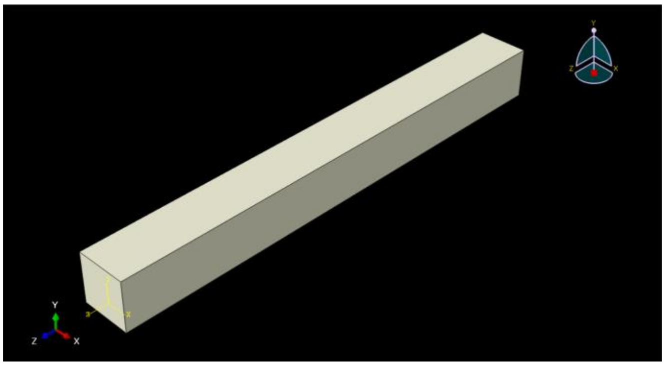

Figure 2.3.1: Beam shape after assembling

2.4 Step

In this phase, we need to choose an approach for determining this step. There are several types of analysis techniques, such as static general, dynamic explicit, that allow us to select the variables that result from what we require after the analysis. We chose dynamic explicit for our analysis.

2.5 Load

In this part, we have to input the loading and boundary conditions. We applied 20 kN uniformly distributed load and the boundary condition was fixed end support on both sides of the beam. So that, we need to define the load module according to boundary conditions.

2.6 Mesh

In this module, we define the size of elements.

Here, the mesh calculations of Concrete all beams:

Mesh Number calculations = Total volume/Small cube volume

$=290\times290\times2820/40\times40\times40$

$=3706$

Here, 40 mm is the global size of rebar, stirrups, and others.

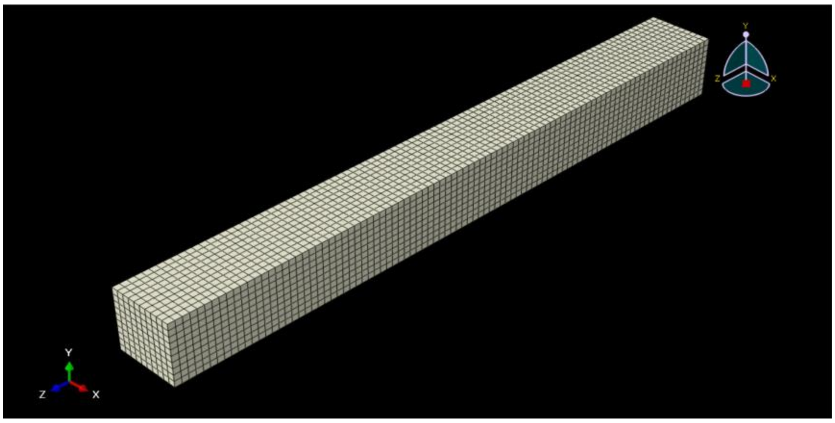

Figure 2.6.1: Mesh

2.7 Visualization

After completing mesh then we have to create the job module then the result will be visualized.

Finally, this section focuses on a detailed method for finite element analysis of Normal and the other three Truss Beams. The solution of the overall structure is found by formulating and combining the attributes of the element.

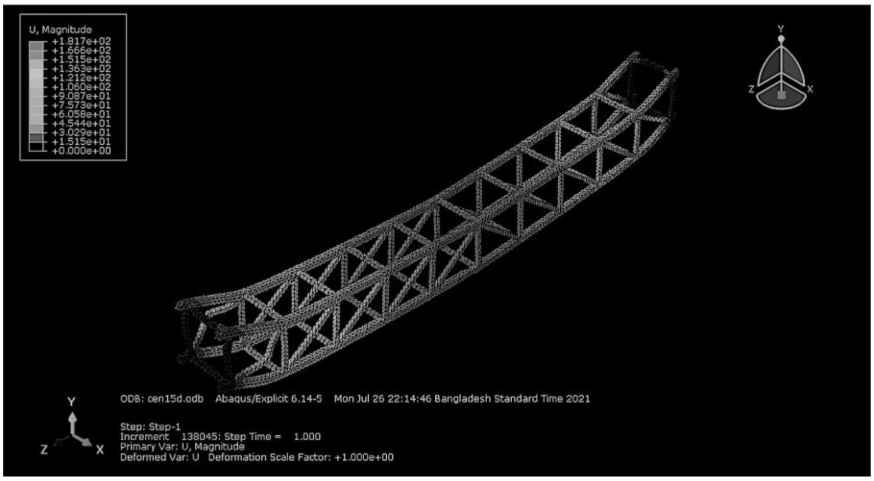

Figure 2.7.1: Visualization of the displacement of steel

3. RESULTS & DISCUSSIONS

The results of the Finite Element Analysis of the normal RC Beam and Three types of truss pattern beams are discussed in this section. ABAQUS software was used to perform a parametric analysis of the RC Beam and other three Truss beams under the same amount of loads, including stress variables and invariants, translational and rotational displacement, and damaget (tension damage in concrete), damagec (compression damage in concrete). A suitable finite element (FE) modeling of concrete using an effective dynamic explicit or implicit or static general method, an acceptable mesh, suitable boundary conditions, loading, and other concrete parameters

3.1 Displacement of Steel

Figure 3.1.1 to Figure 3.1.4 depict steel displacement under the equivalent loading conditions. The displacement occurs with a load of 20kN in all cases. The color fluctuation along the beam illustrates the failing conditions of all the beams. The blue color shows the beam's normal state, the green color represents the first stage of failure, the yellow color reflects the situation before failure, and the red color represents the beam's failure for the applied load.

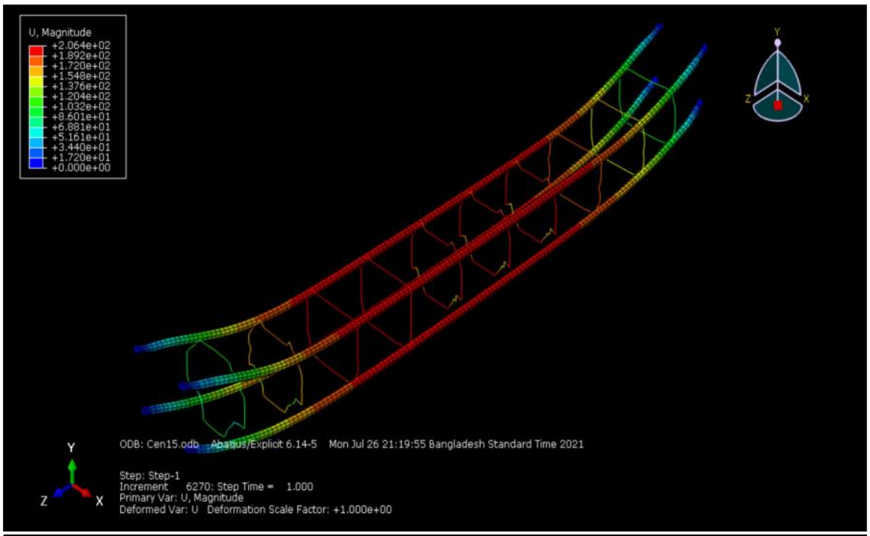

Figure 3.1.1: Normal beam

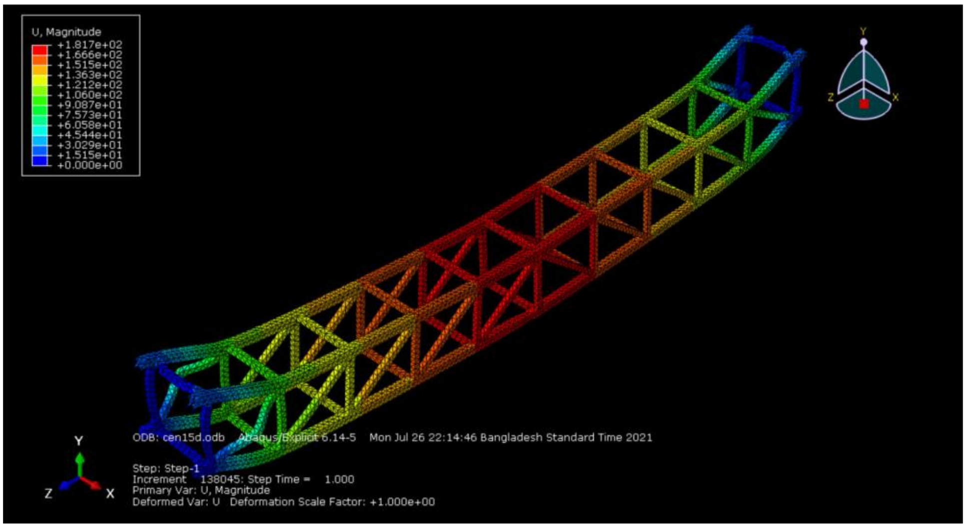

Figure 3.1.2: Howe truss pattern beam

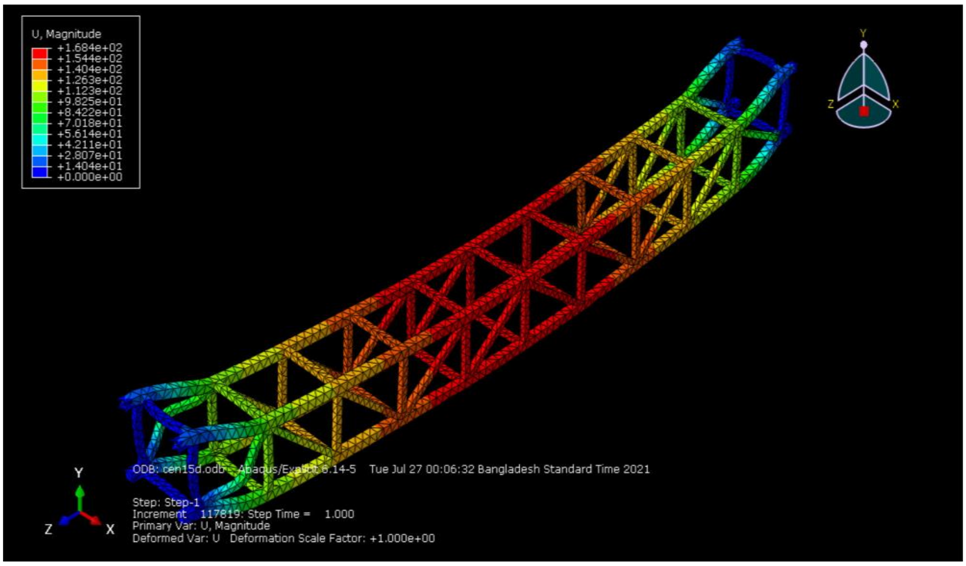

Figure 3.1.3: Pratt truss pattern beam

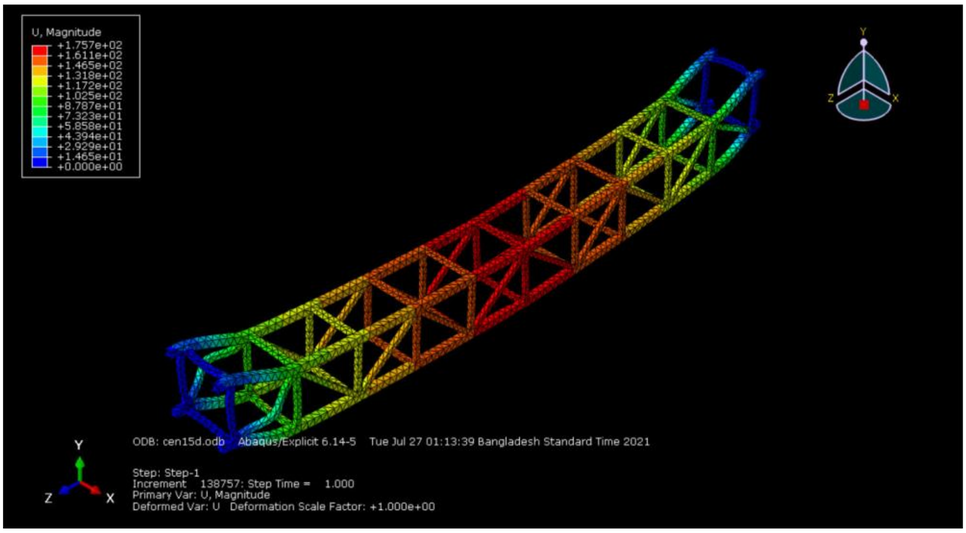

Figure 3.1.: Warren truss pattern beam

3.2 Stress-Strain Behaviour

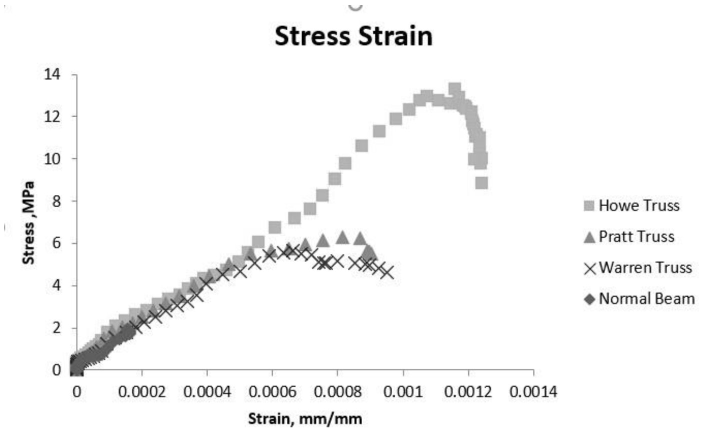

Figure 3.2.1: Stress-Strain curves for all beams

Here all beams' stress-strain behaviour is depicted in Figure 3.2.1. The graph shows that the conventional beam fails at 2 MPa stress, but the Howe, Pratt, and Warren Truss Pattern Beams can withstand about 13MPa, 6.5MPa, and 6MPa stress, respectively. In this case, the conventional beam performs quite weakly when compared to the other truss design beams.

3.3 Load Vs Displacement Behaviour

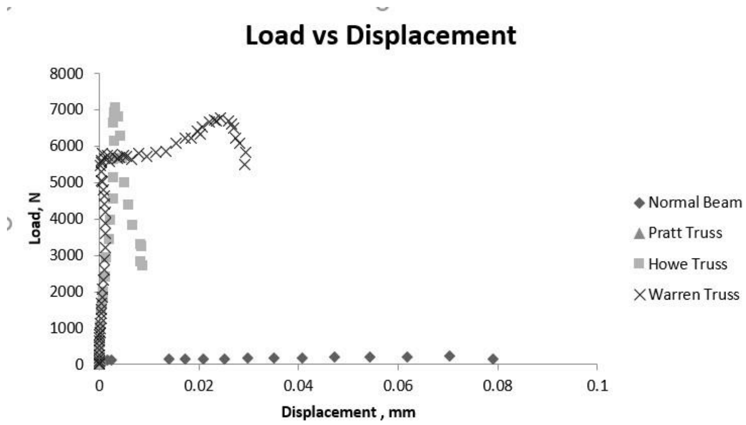

Figure 3.3.1: Load vs Displacement curves for all beams

This section contains a combined graph of Load vs Displacement for all beams studied in this research. The ultimate loads of the Normal Beam, Howe, Pratt, and Warren Truss Pattern Beams are 0.24kN, 7kN, 0.2kN, and 6.5kN, respectively. The steel was initially blue. The color of the steel changes as the load increases. At some stage, it tends to fail due to the increased load and then gradually turns red, indicating steel failure. Thus, the failure was defined in ABAQUS. Throughout this scenario, the Howe Truss Pattern Beam can withstand a significantly greater load than any other beam, but the conventional beam breaks at a far earlier stage than the Howe Truss Pattern Beam.

3.4 Total Energy Vs Time Behaviour

The total energy vs. time curves for all beams are shown in this section of the findings. The energy requirements for a beam to fail can be seen here. In ABAQUS, we set the total time to 60 seconds to analyse this. According to the graph, the energy required to fail the Conventional Beam, Howe, Pratt, and Warren Truss Pattern Beams are 0.94MJ, 4.31MJ, 0.20MJ, and 0.48MJ, respectively. In comparison to all other beams, the Howe Truss Pattern Beam requires more energy to fail.

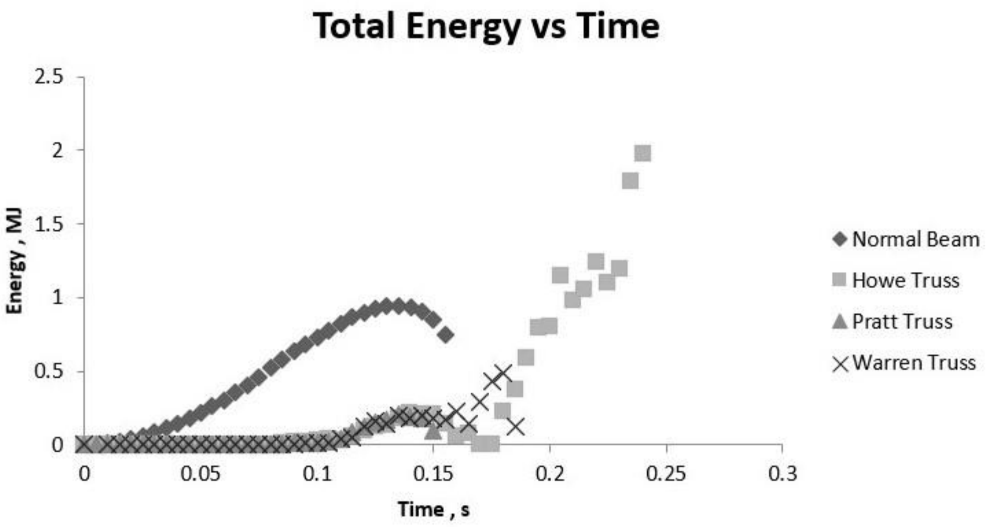

Figure 3.4.1: Total Energy vs Time curves for all beams

4. CONCLUSIONS

Shear failure is the most devastating type of structural breakdown. Our objective in this research was to develop a new shear reinforcement design with a high shear resistance. As a consequence, we designed three truss pattern beam models and compared the results to a conventional beam. The overall comparison's conclusions are presented further below.

- It can be observed from the Stress-Strain curves of all beams that the conventional beam fails at 2 MPa stress under the same loading condition, however one of our designed Howe Truss Pattern Beams withstands over 13MPa stress, which is larger than all of the models.
- The Load vs Displacement Curve shows the same conclusion as the previous one: the conventional beam fails at 0.24kN load, but the Howe Truss Pattern Beam fails at about 7kN load, which is much higher than the conventional beam.
- A similar conclusion can be drawn from the Total Energy vs Time Curve: the Howe Truss Pattern Beam performs significantly better than the conventional one since it requires more energy to fail (about 4.31MJ).

When comparing our three designed truss pattern beams to the conventional beam, it is evident that the Howe Truss Pattern Beam surpasses all other models. As a result, we may conclude that our designed Howe Truss Pattern Beam can be a suitable alternative to conventional beams.

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