Effect of falling height on impact coefficient during dynamic response of truss structure

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Abstract. Impact coefficient is an important parameter for the dynamic response of the truss structure. An effective method to analyze impact coefficient helps the design of truss structure. A finite element model (FEM) was employed to simulate the dynamic response of a truss structure. The FEM for dynamic response was further used to research the effect of falling height on the impact coefficient. Based on the numerical results, the dynamic response of truss structure attenuates greatly. The impact coefficients are different from each other for different falling heights. The impact coefficient increases with the increasing falling height and the relationship between impact coefficient and falling height are nonlinear.

1. Introduction
Truss structure is widely used in bridge, aerospace and construction because of its high ratio of stiffness to mass. Truss structure can be under dynamic loading during its usage. Impact coefficient is an important parameter during the design of truss structure. If the dynamic response of truss structure cannot be evaluated in advance, there would be a risk during the usage of truss structure. Therefore, the impact coefficient should be analyzed to make sure the safety of truss structure.

For uniform beam structure, there is a classical theory to calculate the mechanical response [1]. The theoretical model is useful for the homogeneous beam section. For truss structure, the sections of truss are inhomogeneous; therefore, the available theory is useless to calculate the mechanical response of truss structure. Fortunately, it has been demonstrated that finite element model (FEM) is a valid technology to analyze mechanical properties of truss structure [2-5]. From then on, the FEMs of truss structure has been widely researched. In order to analyze the elastoplastic small deformation, an extended multiscale finite element method was developed for 2D periodic lattice truss materials [6]. Before using FEM to predict the deformation of truss structure, the differences between matrix displacement method and finite element method were analyzed [7]. Based on the stiffness and load matrix of bridge frames, a FEM was established to calculate the lateral displacement under the loading of wind [8]. The initial yield surface of periodic 2D trusses of beams and evolution of the yield surface with ongoing hardening were both added into an asymptotic discrete expansion FEM to simulate the elastoplastic homogenized response of lattice truss structure [9]. In order to realize the geometrically nonlinear analysis of the structures with lattice truss materials, an equivalent continuum multiscale formulation was presented by combining the extended multiscale finite element method with the
co-rotational approach [10]. The static response of truss structure has been widely investigated; however, the effect of falling height on impact coefficient during dynamic response has not been explored.

In this paper, we employed a finite element model (FEM) to calculate the dynamic response of truss structure. A series of FEMs have been established to analyze the dynamic response of truss structure at different falling heights. Finally, the effect of falling height on impact coefficient was discussed.

2. Finite element model
The finite element model (FEM) aimed to simulate the mechanical behavior of truss structure, has been developed by means of ABAQUS 6.11 [11,12]. In order to research in detail the mechanical properties of truss structure, a 3D FEM has been defined accounting for the truss geometry, materials and boundary conditions. A deformable 3D truss model was generated by means of planar commands. Concerning the meshing of the beam, the truss has been discretized by means of shear-flexible elements adopting the global seeds meshing technique. In order to favor convergence and reduce the computational time, the simplest element type has been chosen, the B31, that is a 2-node linear beam in space. Figure 1 illustrates FEM of truss structure. The boundaries for simply supported beam was used here. The bar with the mass of 15.9 kg is a few meters ahead of truss structure. The different FEMs are shown in Table 1. The model consisted of approximately 1430 elements and 1351 nodes. A dynamic explicit procedure type was chosen to calculate the dynamic response of truss structure. When the calculations of the dynamic response have been accomplished, the Mises stress and strain are obtained by means of output databases. Based on the calculated results, the effect of falling height on impact coefficient was analyzed.

![Figure 1. Finite element model (FEM) of 3D truss structure.](image)

| No. of FEM | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------|---|---|---|---|---|---|---|---|
| Falling height (m) | 0.25 | 0.5 | 1 | 2 | 4 | 6 | 8 | 10 |

3. Dynamic response
Using 3D ABAQUS finite element model of truss structure, the dynamic response was researched. Figure 2 and Figure 3 show the strain-time curve and stress-time curve respectively during the impact of bar. Before the impact of bar, both the strain and the stress are zero. Once the bar hits against the truss
structure, the strain and stress increase greatly. As shown in Figure 2 and Figure 3, the strain and stress attenuate gradually. The maximum of strain and the maximum of stress appear at the first time of impact. Based on the calculated results in Figure 3, the dynamic response of truss structure, i.e., the maximum of stress is obtained. According to the classical theory, the static stress of truss structure under the static loading of 159 N can be calculated. Then, the impact coefficient can be achieved by dividing the maximum stress by the static stress.

![Figure 2. Variation of strain with time at the impact zone.](image)

![Figure 3. Variation of stress with time at the impact zone.](image)
The effect of falling height on the dynamic response of truss structure is illustrated in Figure 4. The relationship between impact coefficient and falling height is nonlinear. If the falling height is less than 2m, the impact coefficient increases greatly with the increasing falling height. If the falling height is beyond 4m, the impact coefficient also increases greatly with the increasing falling height. For the falling height between 2m and 4m, the falling height has less effect on the impact coefficient. The impact coefficient is a stable value if the falling height is between 2m and 4m.

![Figure 4. Impact coefficient at different falling height.](image)

4. Concluding remarks
Based on the finite element method of ABAQUS, a finite element model (FEM) was employed to research the effect of falling height on the impact coefficient. According to the simulated results from FEM, the relationship between impact coefficient and falling height is nonlinear. The impact coefficient increases greatly with the increasing falling height for the falling height less than 2m. The impact coefficient is a stable value if the falling height is between 2m and 4m. The impact coefficient also increases greatly with the increasing falling height for the falling height beyond 4m.

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