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USING OPENSEES SOFTWARE IN FIRE

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Abstract

OpenSees is an object-oriented programming tool for creating finite element solutions to model the behavior of geotechnical and structural systems. This application was developed using the programming languages of Python, c++, and Tcl. Since a suitable solution may greatly alter the structural fire reactions, it must be considered when modeling the reaction of tall structures to flames, particularly multifloored fires. Given the difficulty of current modeling methods, the purpose of this work is to use the open-source software "OpenSees for fire" to conduct a thorough analysis of the behavior of buildings and their components during a fire. The findings of utilizing the developed software to overcome a variety of standard issues and to simulate actual fire testing can be presented in this article.

Keywords: *opensees, thermal activity, programming languages, fire testing, fire behavior.*

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1. Introduction

Historically, designers haven't given much thought on how the load and the building interact while designing for fire. It is considered that the fire hazard resistance provided by automatic fire suppression approaches that rely on isolated single-component evaluation under a normal fire time-temperature curve is sufficient. Normal fire evaluation of structural components, in which component capacities are linked to restricting heat, is the conventional method for determining a building's fire damage [1-2].

The primary goal of OpenSees has been to provide state-of-the-art computing tools to analyze the non-linear behavior of building structures exposed to seismic action. The structural reliability and response spectrum features provide a wide variety of dependability estimation techniques [3]. OpenSees has existed for the majority of the past decade, and with its popularity and the contributions of its increasing user group and programmers, it can now do more advanced analyses of building structures than several professional systems.

OpenSees can be a society survey program with extensive simulating capacity in several fields of materials design, allowing for unrestricted collaboration over regional boundaries and extending the useful life of projects and initiatives. The object-oriented approach of system development using C++ is another one of OpenSees' attributes, as it defines the designers and assures that perhaps the structure will grow in a way that seems to be workable, simple to operate, and recyclable by other designers [4-6].

In this article, we provide an outline of how integrating OpenSees into the fire would maintain the OpenSees ethos of being object-oriented and allowing the usage of High-Performance Computing (HPC) technology. The structural frameworks will be repaired and made fireproof due to this effort. The major fields of research and application will assist in the advancement of this functionality [7-9]:

- To simulate the effects of a fire on a building's structural parts by establishing thermal flow boundaries.
- Considerations of small variations in heat transfer characteristics because of the fire outbreak are included in the investigation of heat transmission to building elements.
- Including the thermal properties of materials in the core OpenSees material models and expanding the library to include additional thermo model parameters.
- Including levels comparable to load-induced thermal strain (LITS) or transient thermal strain (TTS), this depends on temperature.
- Adding support for temperature impacts required modifying the existing beam and shell component types in OpenSees.

2. Fire Loading Simulation

This work's purpose is to enable a variety of fire configurations, both homogeneous and heterogeneous, to be applied to the model's borders. The following approaches to modeling the effects of fire loading are presented to achieve this goal.

- Fires in typical compartments after overheating follow the time-temperature curves specified by different regulations and guidelines.
- Fires in naturally occurring compartments after overheating may evolve in several ways, as outlined by the numerous generic time-temperature correlations suggested.
- To provide comparatively higher accurate depictions of heat inside a fire compartment, "region designs" may be constructed using basic energy balancing rules in addition to code-based conventional fires and dynamic natural flames.

When subjected to the initial three varieties of fire loading, the temperature distribution within a given compartment is assumed to be temporally uniform, meaning that a separate temperature value can be used to characterize the heat transfer across the entire compartment at a specific moment in time. Heating may be geographically and regionally varied during the last two classes of loading situations. Radiation and convection fluctuations will be applied to the building to simulate all possible forms of fire loading [10-13].

3. Modeling of heat conduction via structural elements

After establishing the fire boundary conditions, the temporal progression of heat inside the structure may be calculated by computing the thermal performance of the building elements. OpenSees will be modified to include a feature for representing 3D thermal conduction as an entity. The current OpenSees architecture, including the network counting elements, the statistical classes, and solution classes, will be used in the development of an innovative heat transfer analysis method [14].

Heat transport functionality will use OpenSees's fiber sector frame components. Since the biggest temperature variations appear in the bridge of the element instead of along its distance, the nature of heat transport in constructing buildings due to fire lends itself readily to the fiber-type analysis of building elements. A similar situation goes for heat transport analysis, resulting in a structural analysis model with similar characteristics is ideal.

To reduce computing resources and provide consumers with more options, a 2D heat transport analysis function for the structural section will additionally be created for use in situations when heat transfer along the straight line may be ignored. Modeling fires and thermal transmission in this way will make it possible to simulate a variety of basic fireloading circumstances with reasonable ease. If simply a thermal analysis is needed, the measured values from the heat transport modules may be collected or saved for later use. If the fiber parameters are the same as the heat transport discretized, a heat record file will be implemented for all fibers of the frame, and fiber components, and vice versa if the structural assessment would be to occur [15].

Due to the lack of input to the heat transport computation from the mechanical response, building distortion is not accounted for in heat transport analysis in conventional buildings for fire evaluation. To predict the systemic dynamic model, this presumption is enough. A fully linked temperature study, involving transportation systems of multistage materials in the cementitious mixture, is often necessary for localized independent testing of phenomena like cement spalling behavior. Structural destruction should be accounted for in the heat transport concept when examining the effects of earthquakes on buildings. Localized heat transfer is considered amenable to being manipulated as a consequence of the strain value. It appears to reason that damage will result in preferential heat transmission patterns. Figure 1 depicts the heat transfer process in the civil area [21].

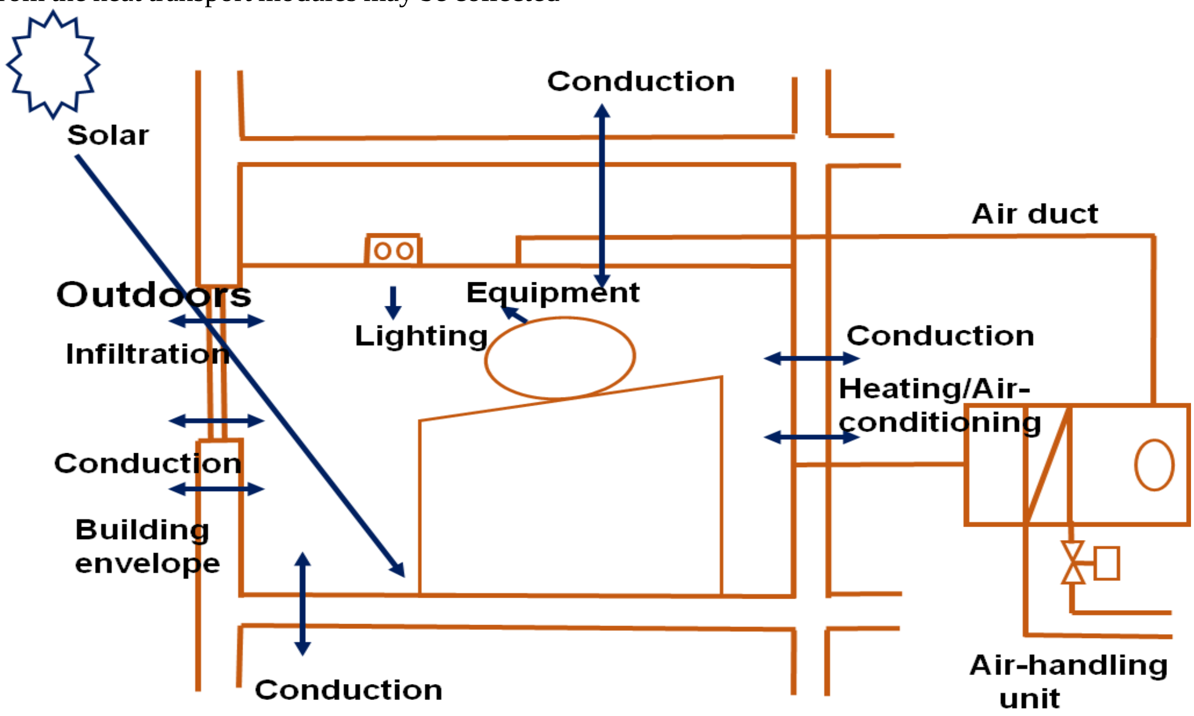

Figure 1: Heat transfer process in buildings

4. Characteristics of materials that vary with temperature.

OpenSees has a wide variety of design methods for structures, each specifying the structural constituent behavior of the material in consideration. Unfortunately, a number of these designs will have to be updated so that temperature-dependent stresses and strain impacts, such as LITS, are considered. Since this information is not readily accessible for the multiaxial situation, the inclusion of thermal dependency will initially only be implemented in the uniaxial metal and concrete systems. Similarly, the portion response in the fiber beam and shell models can be calculated by combining the fiber's load, stress, and heat conditions [15-17].

The heat transport system will also require a fresh set of material behaviors. These will be derived from information used in the construction industry. As was indicated before, a localized pressure indicating injury will be linked to thermal characteristics and specific heat capacity.

5. Thermo-mechanical Schemes

Beam or frame sections are subjected to straightforward thermal operations, including maximum temperature and a constant temperature gradient. Materials are used to apply more comprehensive and accurate heat responses over the region, with the thermal record of every fiber having been made available and analyzed. The heat transfer tools in OpenSees are required to regulate by instances of the abstract class Heat Area. Basic input data or full flame and heat transport evaluations may be used by this method to produce precise temperature distributions for all building structures [18].

6. Result analysis

Steel was modeled using a heating method. The material's behavior is essentially flexible since the elastic limit was set to an infinitely large amount. For this study, we considered a constant factor of heat elongation of $\alpha = 1.2 \times 10^{-5}/°C$ and a temperature-dependent elastic modulus of 200 GPa at room temperature. Material and geometrically linear analysis [MatL and GeoL], material and geometrically nonlinear analysis (MatNL and GeoNL), and both materials and geometrically nonlinear analysis were carried out. A temperature-dependent mechanical property is the only manifestation of nonlinearity in this substance. A strong correlation between OpenSees and analytical solutions for the linear situation is shown in Figure 2.

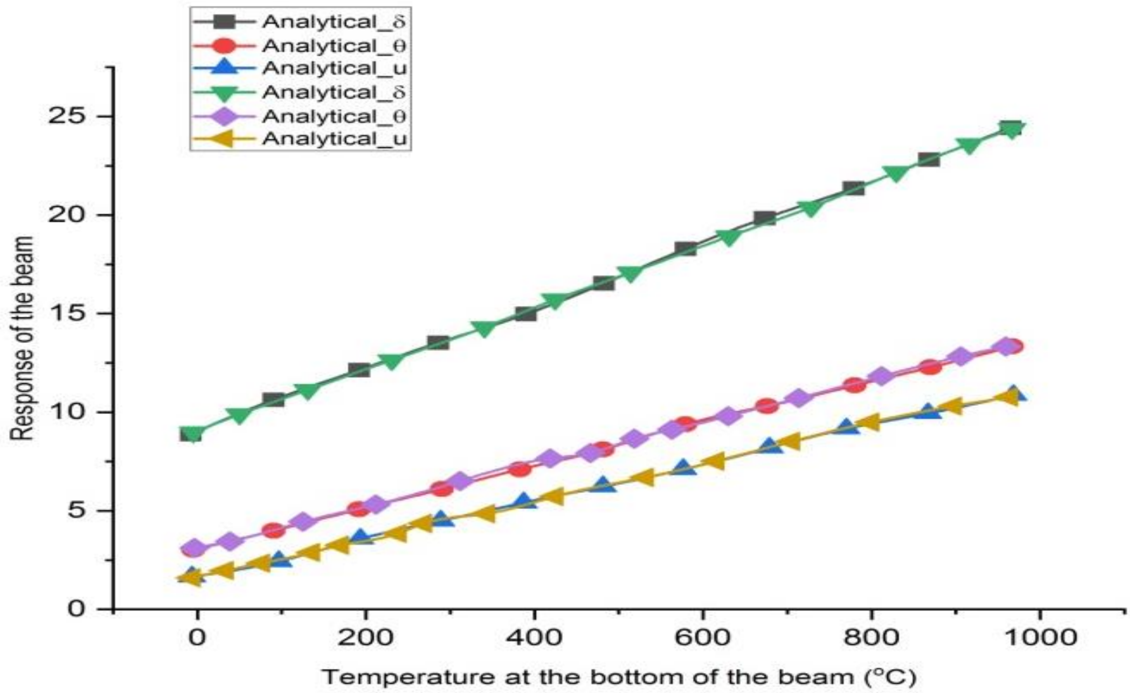

Figure 2: Beam response of OpenSees compared to analytical solutions.

The GNL has a noticeable impact on the beam's mid-span distortion but a much smaller one on its rotation and horizontal displacement. After roughly 600°C, the nonlinear analysis revealed that the beam's midspan distortion had steadily increased and had undergone a steeper slope [19]. This is because the heat bending action, which causes a lower flexing of the beam as the temperature rises, is exacerbated by substance deterioration at high temperatures. As can be seen in figures 4, the beam's rotation and horizontal displacement are both enhanced due to thermal elongation up until 500°C, after which they originated to decrease due to the beam's reducing elastic modulus being incapable of blocking the collected tensile stress and elastic rebound of the extremely cold translational and rotational springs [20].

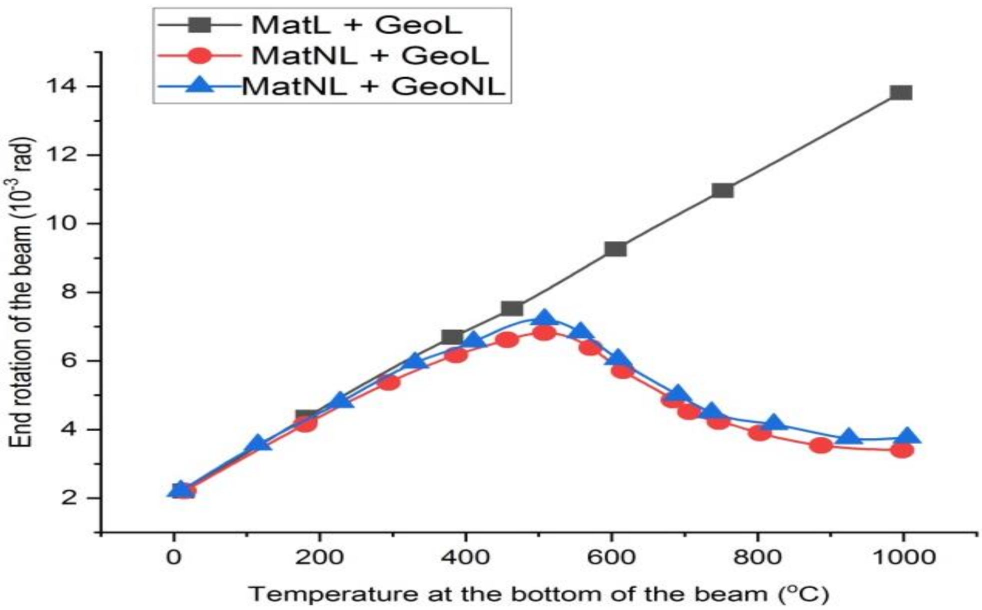

Figure 3: Beam temperature with end rotation

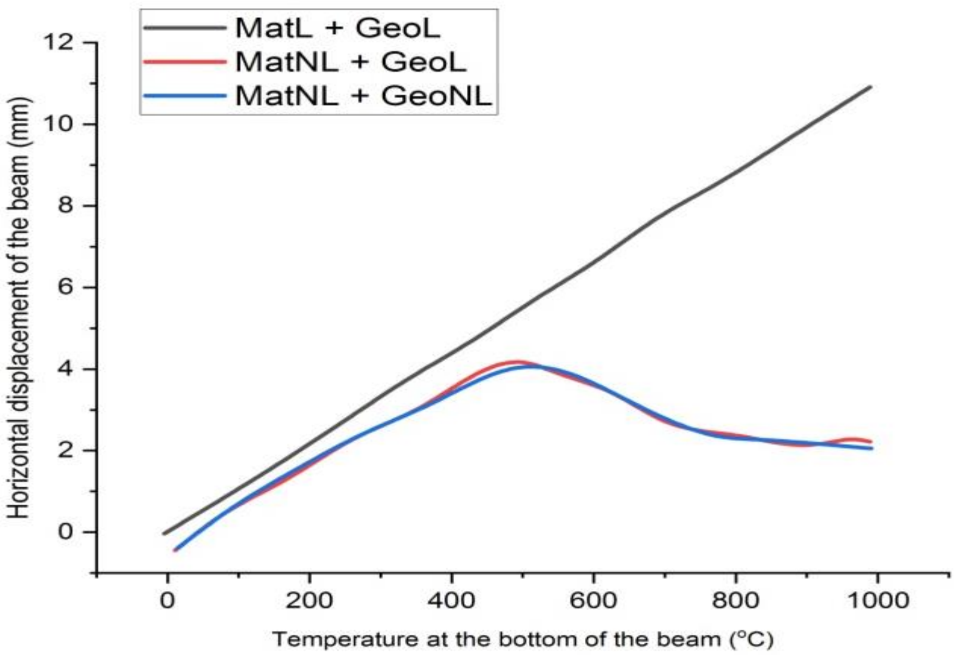

Figure 4: Variation in beam horizontal motion as a function of temperature

7. Conclusion

OpenSees, a free and open-source object-oriented finite element software framework for building construction, has been modified to thermo-mechanical modelling. All new modules will be created according to a detailed strategy. Most of the code that has been put in place so far consists of making new categories out of preexisting OpenSees objects, which has been done solely to implement simple mechanical behaviours. Even if preliminary and comprehensive

findings were provided before, this section will focus on the latter. To complete the fire loading and heat transfer work, a whole new set of classes will need to be added to the framework, and this must be done very carefully so as not to break the continuity with OpenSees' concept and current structure. This study examines how the OpenSees software may be put to use in civil engineering emergencies. The findings prove that OpenSees is a useful tool for enhancing the performance of buildings.

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