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Simulation of fire spreading process and control strategy of high-rise building facade insulation material by combining linear programming and multi-physics field modeling

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Abstract Due to the complex structure of high-rise buildings, the diversity of use functions and other characteristics, resulting in once a high-rise building fire occurs, the number of deaths, injuries, and direct economic losses caused by the number of people is huge. This paper takes the fire incident of the telecommunication building in S city of N province as an example, establishes the fire spread model of high-rise building facade insulation material through Pyrosim software, and constructs its fire spread kinetic model. The linear regression and multi-physics field model are combined to realize the reconstruction of the fire accident scene, so as to realize the accurate simulation and analysis of various parameters in the fire spreading process. It is found that the heat release rate curve of the fire spread of the facade insulation material of the high-rise building is in the form of a double peak, and the first and second peaks appear at about 210s and 840s, respectively, and the heat release rate of the second peak reaches $2.15*10^6$ kW. In the composition of the fire spread, the flame change of the flammable material B3 is the most drastic, and the temperature change is the most rapid. The difference between the simulation results and the measured results is relatively small, and the overall temperature change trend is more consistent with the actual results. By simulating the fire spread process of high-rise building facade insulation materials, it is necessary to strengthen the first mobilization of forces, actively develop flame retardant or non-combustible exterior insulation materials, and multi-point monitoring to enhance the fire rescue initiative when carrying out fire spread control.

Index Terms linear regression, multiphysics field modeling, Pyrosim software, fire spread simulation, fire control

I. Introduction

Under the rapid development of China's national economy, China's construction industry has also been rapid development [1], [2]. Along with this, people's requirements for the safety and comfort of the building system are also getting higher and higher, because the external wall insulation system of the building can effectively meet the building's thermal insulation efficacy, so the external wall insulation materials in the construction of the building has also been widely used [3]-[6]. With the rapid progress of China's economy, there are various kinds of external wall insulation materials, which provide a lot of convenience for people's life [7], [8]. External wall insulation materials, mainly divided into two categories: organic insulation materials and inorganic insulation materials [9]. Because organic thermal insulation materials have high combustion properties, they are prone to burn quickly when a fire occurs causing a fire outbreak, leading to a situation where the fire spreads rapidly [10], [11]. And although inorganic thermal insulation materials have relatively low combustion performance, their thermal conductivity is also relatively large, not easy to waterproof, and prone to temperature expansion and contraction, thus causing problems such as cracking of the external wall, water seepage, and rain leakage [12]-[14]. Since all external wall insulation materials are combustible, they have caused many serious fire problems as well as some potential safety problems [15], [16]. Moreover, when these materials burn, the fire will quickly spread throughout the entire floor, which is very dangerous, especially in high-rise buildings [17], [18].

The façade of modern high-rise buildings usually uses a large number of insulation materials, decorative materials, and vertical tube shafts such as internal elevator shafts, cable shafts, and air ducts, which do not meet the technical standards for fire protection, and are prone to the "chimney effect" once the fire starts, coupled with external wind, resulting in rapid fire spread and three-dimensional combustion, which can easily cause mass deaths and injuries or serious accidents [19]-[22]. Due to the difficulty of extinguishing fires in facade insulation, it is difficult for fire-fighting facilities to function when a fire occurs [23], [24]. Therefore, the study of simulation and control strategies for fire spreading process of facade insulation in high-rise buildings is a problem that is currently faced and needs to be solved urgently.

Fire is one of the major disasters that most commonly and frequently threaten social development and and public safety. With the rapid development of the world economy and the increasing urban population, high-rise buildings have gradually become an inevitable trend in the development of modern society. In this paper, the fire incident of the telecommunication building in S city of N province is selected as the simulation object, and on the basis of analyzing the basic control equations of fire spreading and the low Mach number assumption, the fire spreading dynamics model is constructed by combining with the Pyrosim software and the fire load and heat release rate in the process of fire spreading are explored. Based on Pyrosim software, a three-dimensional model of fire spread of high-rise building facade insulation was established, and linear regression and multi-physics field model were introduced for fire accident scene reconstruction, which provided support for accurate simulation of changes in temperature, visibility, and heat release rate of the fire spread scene. Based on the numerical simulation results, specific control strategies for the fire spread of high-rise building facade insulation materials are proposed.

II. Relevant technology base

With the rapid development of the economy, people's culture, living standards gradually improved, and constantly prompted the construction industry to further prosperity and development. High-rise buildings and underground buildings more and more, a variety of new polymer synthesized materials and a large number of emergence and is used in building structures, interior decoration and furniture furnishings. High-rise and underground construction of a large number of construction, the use of a variety of new synthetic materials to a certain extent to alleviate the rapid growth of human needs and resources increasingly tense between the contradiction, but accordingly brought new problems. The extensive use of modern decorative materials, to firefighting work more difficult, new materials, the heat release rate is equivalent to many times the traditional materials, smoke occurs at a much higher rate than traditional materials. The hazard of toxic gases generated by fire is more severe, and fire smoke has become one of the main causes of casualties.

II. A. Linear Programming Models

II. A. 1) Mathematical modeling of linear programming

Linear programming is an important branch of operations research, an applied science, which is a mathematical method to assist people in scientific management, and is an important part of mathematical planning. The problem considered by mathematical planning is how to plan a collection of interrelated activities in an optimal way, when the objective function and the constraint function of mathematical planning are both linear functions, this mathematical planning is called linear programming [25].

Linear programming studies a mathematical theory and method of the extreme value problem of a linear objective function under linear constraints, and its essence is to solve the extreme value problem of a linear function under the constraints of a linear equation or inequality. How to establish a mathematical model of a linear programming problem? Usually, the first step is to determine the decision variables, which are the unknowns to be solved, and the selection of decision variables is not unique. But the selection of decision variables is appropriate, directly affecting the establishment of mathematical planning model of the degree of difficulty, it is the establishment of the model of the most critical factors. Then determine the objective function, i.e., the goal to be achieved, which is expressed by the expression of the decision variable. Finally, the constraints are determined, i.e. the limitations to achieve the optimization goal, which are expressed by the equations or inequalities of the decision variables. The standard type of linear programming model is described in mathematical language as follows:

$$\min(\max)Z = c_1x_1 + c_2x_2 + \cdots + c_nx_n \tag{1}$$

$$\text{Constraint conditions:}\begin{cases} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \le (\text{or} =, \text{or} \ge) b_2 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \le (\text{or} =, \text{or} \ge) b_1 \\ \vdots \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \le (\text{or} =, \text{or} \ge) b_m \\ x_1, x_2, \cdots, x_n \ge 0 \end{cases} \tag{2}$$

The standard type of linear programming model is characterized by all decision variables being greater than or equal to zero, all constraints being linear equations, all qualifying coefficients being non-negative, and the objective function being sought as a minimum or maximum value. If the linear programming problem is not the standard type, it can be transformed into the standard type through a series of mathematical deformation.

II. A. 2) Linear Programming Solution Steps

Generally, the problem of finding the maximum or minimum value of a linear objective function subject to linear constraints is collectively called a linear programming problem. The solutions that satisfy the linear constraints are called feasible solutions, and the set consisting of all feasible solutions is called the feasible domain, and the decision variables, constraints, and objective function are the three elements of linear programming [26].

The general mathematical model of a multi-objective linear programming problem is described as the general mathematical model of a multi-objective linear programming problem with r objectives, m decision variables, and n constraints:

$$MaxZ = c * X \tag{3}$$

$$s.t\begin{cases} Ax \le b \\ X \ge 0 \end{cases} \tag{4}$$

where $Z = (Z_1, Z_2, \cdots Z_z)^{\text{ú}}$ and $Z_1 = c_{11}x_1 + c_{11}x_1 + \cdots c_{1a}x_a$.

$$\begin{gathered} (i = 1, 2, \ldots r) \\ A = \begin{pmatrix} a_{11}a_{12}\cdots a_{18} \\ a_{11}a_{12}\cdots a_{18} \\ a_{11}a_{12}\cdots a_{18} \end{pmatrix} \\ b = (b_1 b_2 \cdots b_n)^{\text{ú}} \\ x = (x_1, x_2, \cdots, x_x)^{\text{ú}} \end{gathered} \tag{5}$$

The optimal solution can be obtained by solving the target model.

In general, the actual problem can be abstracted into a mathematical model, and then solved using a linear programming problem, the final result is the optimal solution of the linear programming problem, in other words, the best way to solve the actual problem.

II. B.Fire spread base model

II. B. 1) Basic control equations

Fire combustion is a process that incorporates chemical reaction equations where substances undergo heat transfer, heat transfer and motion, and three basic sets of theoretical models are provided here, namely, hydrodynamic equations, combustion models, and thermal radiation models. The details are as follows:

(1) Fluid dynamics equations

The mass conservation equation can be expressed as:

$$\frac{\partial \rho}{\partial t} + u \cdot \nabla \rho = -\rho \nabla \cdot u \tag{6}$$

The component conservation equations can be expressed as:

$$\frac{\partial \rho Y_i}{\partial t} + u \cdot \nabla \rho Y_i = -\rho Y_i \nabla \cdot u + \nabla \cdot \rho D_i \nabla Y_i + m_i \tag{7}$$

The momentum conservation equation can be expressed as:

$$\frac{\partial u}{\partial t} + u \cdot \omega + \nabla H = \frac{((\rho - \rho_0)g + f_i + \nabla \cdot \tau_{ij})}{\rho} \tag{8}$$

$$\nabla^2 H = -\frac{\partial (\nabla \cdot u)}{\partial t} - \nabla \cdot F \tag{9}$$

where ρ is the gas density, u is the velocity vector, g is the gravitational acceleration, f is the external force vector, and τ_{ij} is the stress tensor of the Newtonian fluid [27].

The pressure equation can be expressed as:

$$F = u \cdot \omega - \frac{((\rho - \rho_0)g - f_i - \nabla \cdot \tau_{ij})}{\rho} \tag{10}$$

$$P(z,\tau) = \rho \cdot T \cdot R \sum \frac{Y_i}{W_i} \tag{11}$$

The equation of state can be expressed as:

$$P(z,\tau) = \rho \cdot T \cdot R \sum \frac{Y_i}{W_i} \tag{12}$$

(2) Combustion modeling

The process of fire combustion combines the interaction between turbulent motion and chemical reactions, a complex phenomenon that makes it difficult to predict accurately. When a fire occurs, the complexity of chemical changes, energy release, and gas flow involved in the combustion process makes it extremely difficult to estimate and regulate. Therefore, in order to study fires in depth, a simulation tool coupled with a fire combustion model is required. In Pyrosim's fire simulation simulation, the rate-limiting model and the mixed fraction combustion model are two crucial combustion models. The simulated combustion reaction model can be generally written as:

$$V_F^{Fuel} + v_0 O_2 \rightarrow \sum_i V_{p,i}^{Products} \tag{13}$$

where v_i is the chemical equivalency coefficient, and the subscripts F, O, P represent fuel, oxygen, and combustion products, respectively.

(3) Thermal radiation model

Radiation, is one of the core ways of transferring heat outward from an object during a fire in the form of electromagnetic wave motion. In the process of combustion reaction, the thermal radiation released by the flame is strongly influenced by a number of factors, such as the temperature condition of the medium, the medium's ability to absorb the radiation, and the efficacy of the scattered radiation. In the study of problems related to thermal radiation, the approximation method is usually adopted to simplify the treatment. This method is mainly to ignore other factors that have a small effect on the intensity of radiation, and instead use the thermal radiation heat transfer model for calculations.

The radiative transport equation for gas radiative heat transfer incorporating absorption, emission and scattering processes is:

$$\begin{aligned} s \cdot \nabla I_\lambda(x,s) &= -[k(x,\lambda) + \sigma_z(x,\lambda)] I(x,s) \\ &+ B(x,\lambda) + \frac{\sigma_z(x,\lambda)}{4\pi} \int \Phi(s,s) I_\lambda(x,s) d \end{aligned} \tag{14}$$

where $I_\lambda(x,s)$ is the intensity of radiation at wavelength λ, S is the direction vector on the intensity of radiation, and $\sigma_s(x,\lambda)$ is the scattering coefficient. $B(x,\lambda)$ is the emission source term, and the integrals on the right side of the equation refer to the scattering terms coming in from different directions as steric angles.

In practice in simulations, it is common to turn the spectrum of radiation into several different bands, and then integrate over all the waves to arrive at a computational equation for radiation as:

$$s \cdot \nabla I_n(x,s) = k_n(x,\lambda)[I_{b,n}(x) - I_n(x,s)], n = 1,2 \ldots N \tag{15}$$

where I_n is the radiation intensity in band n and k_n is the average of the absorption coefficients in band n.

After calculating the radiation intensity for each band, the total radiation intensity can be summarized as:

$$I(x,s) = \sum_{n=1}^{N} I_n(x,s) \tag{16}$$

The diffuse gray surface radiation intensity boundary conditions are as follows:

$$I_w(s) = \varepsilon I_{bw} + \frac{1-\varepsilon}{\pi} \int_{s \cdot n_w} I_w(s') \, | \, s' \cdot n_w \, | \, d\Omega \tag{17}$$

where $I_w(s)$ is the intensity of radiation received by the object, ε is the radiative emission coefficient, and I_{bw} is the intensity of blackbody radiation on the surface of the object.

II. B. 2) Low Mach number assumption

The fire smoke flow velocity is low, in order to obtain the information propagating at the speed of sound, the calculation needs to use a very small time step, which greatly increases the computational time consuming, which is very uneconomical in practical calculations. For the characteristics of the fire flow field, some researchers have proposed a model equation for thermally driven buoyant flow, which decomposes the pressure $p(x_i,t)$ into three parts: the back pressure $p_0(t)$, the static pressure $-\rho_\infty gz$, and the flow-induced pressure perturbations $\tilde{p}(x_i,t)$, i.e:

$$p = p_0 - \rho_\infty gz + \tilde{p} \tag{18}$$

where ρ_∞ is the ambient atmospheric density and z is the coordinate in the vertical direction in the gravity field.

Normally p_0 is constant and $-\rho_a gz$ and $\tilde{p}$ are small. However, if the fire phenomenon in a confined space is studied, p_0 increases with time during the growth phase of the fire initiation; if a large space with dimensions in the order of kilometers in the height direction is studied, p_0 is no longer a constant, but is a quantity that varies with height.

For low Mach number flows, it can be assumed that temperature and density are inversely proportional. Therefore, the pressure $p(x_i,t)$ can be replaced by the space-averaged pressure $p_0(t)$ in the equation of conservation of energy and the equation of state, and the generalized set of control equations can be reduced to a set of model equations applicable to the low Mach number flow, viz:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho u) = 0 \tag{19}$$

$$\frac{\partial(\rho u)}{\partial t} + \nabla \cdot (\rho uu) + \nabla p = \rho g + \nabla \cdot \tau \tag{20}$$

$$\frac{\partial}{\partial t}(\rho h) + \nabla \cdot (\rho hu) = \frac{dp_0}{dt} + \dot{q}'' - \nabla \cdot q \tag{21}$$

$$\frac{\partial}{\partial t}(\rho Y_i) + \nabla \cdot (\rho Y_i u) = \nabla \cdot (\rho D_i \nabla Y_i) + \dot{m}_i'' \tag{22}$$

$$p_0(t) = \frac{\rho RT}{M} = \rho RT \sum_i \left(\frac{Y_i}{M_i} \right) \tag{23}$$

The low Mach number flow correction model serves two purposes:

(1) Replacing $p(x_i,t)$ with $p_0(t)$ filters out acoustic waves with much higher velocities than the fire-heat-driven flow, so that the time step for numerical calculations is no longer limited by the high-speed acoustic waves, but depends only on the velocity of the fire-heat-driven flow.

(2) The modified equation of state reduces the number of independent variables in the original set of equations by one, simplifying the solution of the equation.

II. C.Pyrosim software

II. C. 1) Pyrosim analysis software

Pyrosim software is developed by the National Institute of Standards and Technology (NIST) based on the principles of computational fluid dynamics for simulating sudden fire conditions, and is widely used in the field of building fire safety design and evaluation [28]. Pyrosim has the following characteristics in performing fire simulation:

(1) Intuitive interface: Pyrosim provides an intuitive and easy-to-use user interface for model creation, parameter setting and analysis of simulation results.

(2) Multiple modeling tools. You can quickly create geometric models of buildings, add fire sources, smoke vents and other elements.

(3) Various function modes. Users can flexibly set various parameters of the fire scene, such as the location of the fire source, intensity, combustion time and simulation accuracy, etc., to study the change rule of fire smoke propagation, temperature distribution and other factors in different modes.

(4) Visualization of results. It can generate rich simulation results and animations to visualize the development process and the influence range of the fire.

Based on the above features, Pyrosim can provide effective help for assessing fire risk, developing evacuation strategies and fire control programs.

II. C. 2) Pyrosim simulation process

Figure 1 shows the simulation and analysis process of Pyrosim software. In general, Pyrosim fire numerical simulation software sets parameters, establishes a physical model, imports FDS for numerical simulation, and finally uses Smokeview to observe the dynamic smoke flow and spread of the total process, uses the data obtained from the model simulation to draw the curve of heat release rate (HRR), temperature, visibility, gas concentration, and other changes in the course of time, and uses the obtained fire Characteristic parameters obtained are used to analyze and study the fire situation.

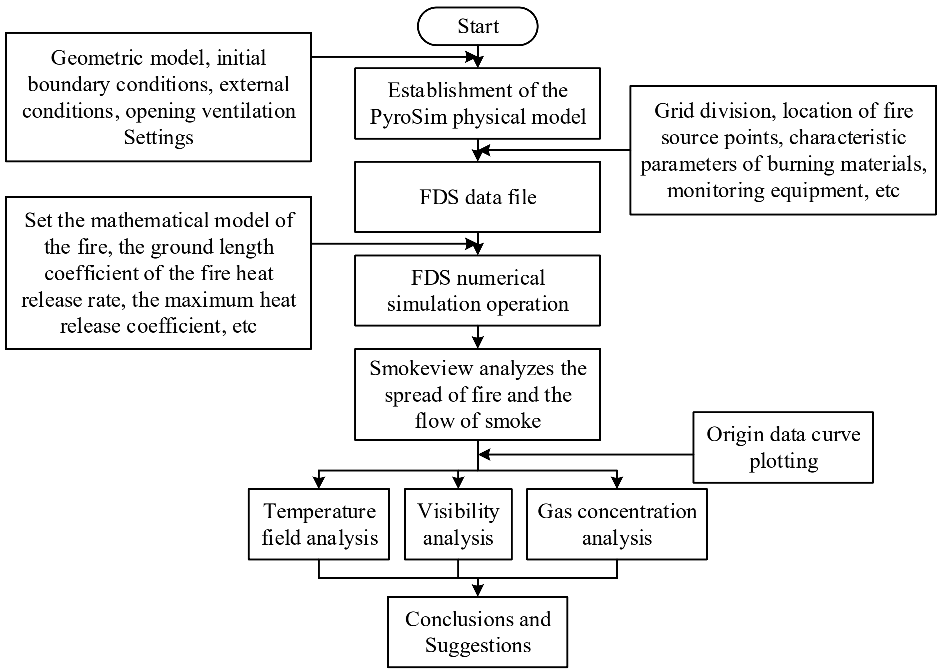


Figure 1: The simulation analysis process of Pyrosim software

III. Simulation and control of fire spread of thermal insulation materials for facades of high-rise buildings

Among the many types of fires, building fires are the most threatening and destructive to human life and property. Building fires occur in places where people are more concentrated, and once a fire occurs, it will cause direct harm to people's lives and property, and in serious cases, it will lead to huge casualties. It is generally believed that the objective reasons for this situation are mainly the structural form of the building and the types of combustible materials have undergone a large change, while the fire technology and efforts have not yet kept pace. The use of a large number of new high-polymer building materials and household items has greatly increased the fire load of buildings, thereby increasing the severity of fires and the difficulty of fire prevention and suppression in these areas.

III. A. Dynamic modeling of fire spread

III. A. 1) Fire dynamics equations

The fire combustion process is a heat and mass transfer process, and the FDS is mainly guided by the equations of conservation of mass, conservation of momentum, and conservation of energy, expressed as follows:

Conservation of mass is:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \vec{u} = 0 \tag{24}$$

Momentum conservation is:

$$\frac{\partial}{\partial t}(\rho \vec{u}) + \nabla \cdot \rho \vec{u}\vec{u} + \nabla p = \rho g + f + \nabla \cdot \tau_{ij} \tag{25}$$

Energy conservation is:

$$\frac{\partial}{\partial t}(\rho h)+\nabla\cdot\rho h\vec{u}=\frac{Dp}{Dt}+\dot{q}-\nabla\cdot\vec{q}+\Phi \tag{26}$$

The ideal gas equation of state is:

$$p=\frac{\rho RT}{\bar{W}} \tag{27}$$

where ρ is the gas density $\vec{u}\vec{u}h=^{T}\int C_p(T^{'})dT^{'}$, g is the gravitational acceleration, f is the external force vector, τ_{ij} is the Newtonian fluid viscosity stress tensor, h is the sensible enthalpy, P is the pressure, and $\dot{q}^{*}$ is the rate of heat release per unit volume. $\dot{q}^{"}$ is the heat flux vector, T is the temperature, Φ is the dissipation function, R is the ideal gas constant, and $\bar{W}$ is the molecular weight of the gas mixture.

The flow field can be differentiated between large scale structure and small scale structure, large eddy simulation is to use a filter width to filter the control range between large scale structure and small scale structure so that all variables are differentiated between large scale structure and small scale structure.N-S equations directly simulate the large scale quantities, the large scale eddy motion determines the turbulent flow of the fire flue gas, and the direct simulation of the large scale structure can get the real structural state.

Smagorinsky sublattice model is a model often used by Pyrosim, according to the Smagorinsky sublattice model, the hydrodynamic viscosity coefficient is expressed as:

$$\mu_{LES}=\rho(C_z\Delta)^2\left[\frac{1}{2}(\nabla u+\nabla u^T)\cdot(\nabla u+\nabla u^T)-\frac{2}{3}(\nabla\cdot u)^2\right]^{\frac{1}{2}} \tag{28}$$

where $\Delta=(\delta x\delta y\delta z)^{1/3}$ and C_z is Smagorinsky's constant. The thermal conductivity coefficient coefficients of the fluid are denoted as:

$$k_{LES}=\frac{\mu_{LES}C_p}{\Pr} \tag{29}$$

$$(\rho D)_{i,LES}=\frac{\mu_{LES}}{Sc} \tag{30}$$

where Sc is the Schmidt number of the fluid, $\Pr$ is the Prandtl number, and C_p is the constant pressure specific heat of the fluid.

Large eddy simulations are capable of handling turbulence and buoyancy interactions and are widely used in the simulation of fire development processes.

III. A. 2) **Fire load studies**

Fire load is the total heat generated by the complete combustion of all combustible materials in a building, and fire load is an essential element in the study of the full developmental stages of a fire. Fire load can be divided into three categories, namely, fixed fire load Q_1, which refers to combustible materials in a room that remain essentially unchanged, movable fire load Q_2, which is additionally arranged to fulfill the function of the room's use, and temporary fire load Q_3, which mainly refers to combustible materials brought in by building occupants temporarily and stay for a short period of time combustible material.

The fire load can be written as:

$$Q=Q_1+Q_2+Q_3 \tag{31}$$

The fire load density can be written as:

$$q=\frac{Q}{A}=\frac{Q_1+Q_2+Q_3}{A} \tag{32}$$

Since the Q_3 uncertainty is so large that its effect is usually not considered, there is:

$$q = \frac{Q_1 + Q_2}{A} = q_1 + q_2 \tag{33}$$

where q_1 and q_2 are the fixed fire load density and active fire load density respectively.

(1) Determination of Fixed Fire Load

Fixed fire load Q_i generally does not change in the life cycle of the building, fixed fire load density q_1 can be written as:

$$q_1 = \frac{Q_1}{A} = \frac{1}{A}\sum M_i H_i (MJ \cdot m^2) \tag{34}$$

where M_i is the mass of fixed combustible material in the room, H_i is the calorific value of combustion of a fixed combustible material, and A is the room area.

For the mass of each combustible substance M_i can be calculated according to the following formula:

$$M_i = A_i bd \quad (kg) \tag{35}$$

where A_i is the area of a combustible material, b is the thickness of the combustible material, and d is the capacity of the combustible material.

(2) Determination of movable fire loads

Determine the movable load Q_2 than to determine Q_1 to be difficult, because the material in a room is too variable. Commonly used methods of calculation are computational statistics and evaluation. To wit:

$$q_2 = \frac{Q_2}{A} = \frac{1}{A_i}\sum n_i \tag{36}$$

where n_i is the total calorific value of combustion of a single piece of furniture or object.

III. A. 3) Rate of heat release from fire

The heat release rate (HRR) of a fire represents the parameter of heat released from the combustion phenomenon at a given time for a given test parameter. This indicator represents the change in the temperature produced by the fire over time, and its determination determines the amount of temperature in the fire room, so the heat release rate is a key factor in determining the course of the fire. Depending on the fire development process, the heat release rate of a fire includes steady state and unsteady state modes. The fire heat release rate focuses on the calculation of multiple periods such as initial development, ignition and full development, the first two periods can effectively determine the detailed progress speed of a particular fire, and the last period can determine the potential maximum size of the fire. The index will change as the development process changes, so that in each development process should be considered more in line with the actual effect of the fire, which will have an impact on the simulation results.

(1) Steady state development

Assuming that the fire develops as a steady state fire, its heat release rate is:

$$\dot{Q} = \Phi \times \dot{m} \times \Delta H \tag{37}$$

where $\dot{Q}$ denotes the rate of heat release, Φ is the burning rate factor, $\dot{m}$ is the mass burning rate of the ignition source material, and ΔH is the calorific value of the ignition material.

(2) Unsteady state development

It is assumed that the fire will vary accordingly with time, and that this growth pattern grows roughly according to the exponential law of time. This takes into account the weakening phase and is closer to what actually happens. For the actual existence of non-stationary fires and other characteristics, it is able to be expressed by means of the T-squared model, namely:

$$\dot{Q} = \alpha t^2 \tag{38}$$

where $\dot{Q}$ in α denotes the rate of heat release at the fire source, α denotes the growth coefficient, and t denotes the development time.

For the setting of α, two main factors are considered: fixed load and non-fixed load. Among them, the fixed load mainly includes the insulation and decorative materials of the internal and external walls of the building, as well as the decorative materials of the interior, etc.: the non-fixed load mainly includes the insulation materials and wooden boards that are temporarily stacked. Therefore it can be expressed as:

$$\alpha = \alpha_f + \alpha_m \tag{39}$$

where α_m is the effect of finishing materials on the interior and exterior walls and ceiling of the building, α_f can be expressed as:

$$\alpha_f = 2.6 \times 10^{-6} q^{5/3} \tag{40}$$

where q is the fire load density.

This indicator is the room, all combustibles completely combustion of the heat appeared, and the corresponding reference area formed by the detailed ratio. Its calculation can be completed by the following formula, i.e.:

$$q = \frac{\sum m_c H_c}{A_f} \tag{41}$$

where q denotes the fire load density, m_c denotes the total mass of the ignition source material, H_c denotes the effective calorific value of the ignition source material, and A_f denotes the total area of the floor in the room.

The H_c can be referenced to a specific oxygen bomb calorimeter method for detailed testing, and the calorific value parameters can be referenced to the calorific value descriptions of materials commonly used in buildings in related studies.

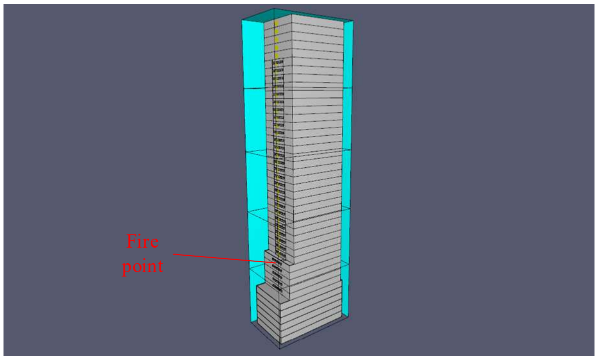
III. B. Fire spread scenario construction

III. B. 1) Case background information

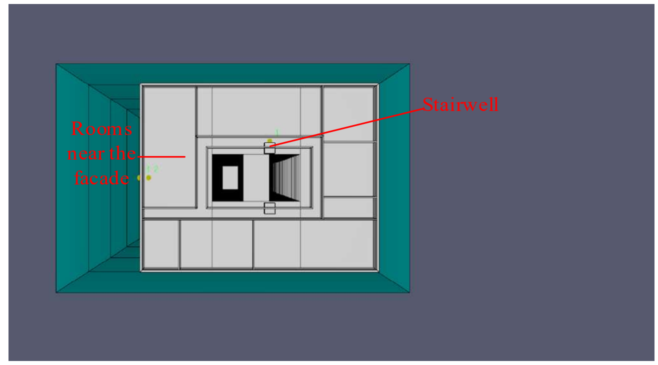
This paper takes the fire incident of the telecommunication building in S city of N province as an example. The building has 40 floors above ground and 3 floors underground, with a building height of 195.5 meters, including 216 meters of building modeling structures, and a standard floor area of 1450.2 square meters. 8 to 38 floors of the building's exterior wall insulation is aluminum composite panel, aluminum composite panel is a kind of exterior wall insulation panel whose surface is flame-retardant material, and its core is polyethylene and other combustible materials. 1 to 7 floors of the exterior wall are dry-hanging granite curtain wall, and 39 to 40 floors are outdoor advertisement boards. The 1st to 7th floors are dry-hung granite curtain walls, and the 39th to 40th floors are outdoor billboards. The cause of the fire in the telecom building was the unextinguished cigarette on the 8th floor that ignited the flammable materials such as wood chips and paper shavings outside the platform on the west side of the 8th floor, which led to the ignition of the building's exterior decorative wall and thermal insulation materials. The weather that day was sunny, with a southeast wind of force 3. The fire spread rapidly upwards to 219 meters, i.e. the 40th floor (top floor) of the main building, and the overall burning time was about 20 minutes. The fire accident caused a total of about 3,500 square meters of overfire area on the exterior walls and 420 square meters of overfire area in the interior.

III. B. 2) Three-dimensional modeling

In this paper, Pyrosim software is used to construct the main appearance of the telecommunication building from 1 to 40 floors as well as the internal structure, as shown in Fig. 2, of which Fig. 2(a)~(b) are the external and internal structures, respectively. Combined with the real fire situation and calculation accuracy and other conditions, the 3D model of the building is established according to the actual size, but the model is simplified to a certain extent.The total calculation area of the FDS is selected as (length×width×height=65m×40m×220m), and the mesh size is divided into (0.6m×0.6m×0.6m), and the total number of meshes is about 5.2*10^5. The 1st to the 7th floor and the 38th to the 40th floors The facade material is set as non-combustible material according to the actual situation, and the 8th to 38th floors are set with four cases of facade thermal insulation materials as wood, PVC, expanded polystyrene, and polyethylene respectively to carry out this study.The 8th to 38th floors are equipped with four spaces on each floor, and the middle of them are stairwells and elevator shafts. The left side is the side close to the fire point. The interior floor slabs and interior walls were set up as noncombustible materials. In order to study the effect of temperature on the evacuation of people, according to the evacuation path of people, temperature collection points are set up at the left side of the 8th to 38th floors along the middle of the facade towards the outer and inner walls near the room and the stairwell entrances and exits to collect the temperature during the combustion process. This is shown in Fig. 3, where Fig. 3(a)~(b) shows the locations of the detectors in the interior and exterior, respectively.

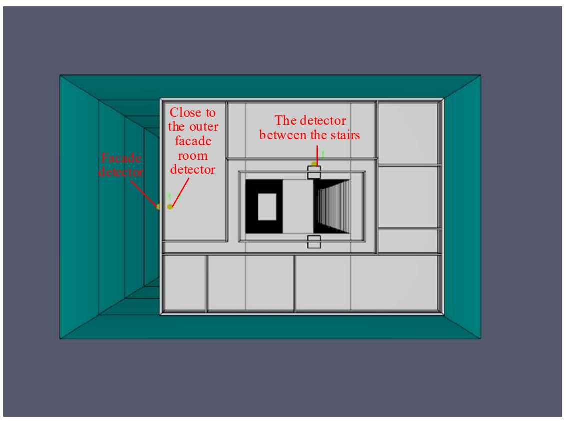


(a) External structure

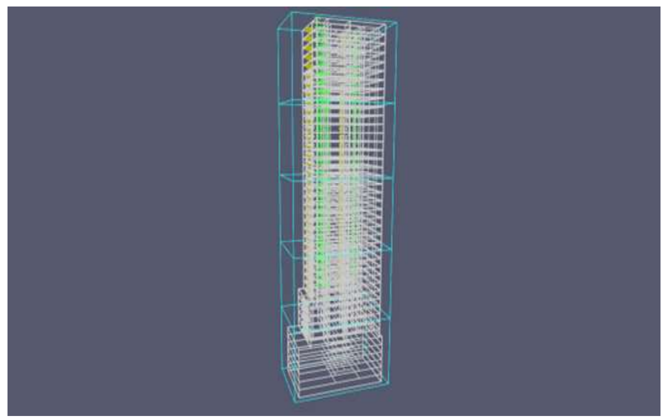


(b) Internal structure

Figure 2: A model of a telecommunications building



(a) External structure



(b) Internal structure

Figure 3: A model of a telecommunications building

III. B. 3) Fire incident reconstruction

In order to realize the effective simulation of the fire spreading process of high-rise building facade insulation materials, this paper combines the large vortex simulation of fire spreading dynamics with the linear programming model, so as to realize the reconstruction of the fire accident, and to provide support for the simulation and analysis of the relevant data in the fire spreading process, and its specific process is shown in Figure 4.

Combined with the above flowchart, its specific realization steps are obtained as follows:

Step1 Determine the optimization region, objectives and parameters. According to the investigation report, in the local area D, the fire develops to the time node T_0 with a certain iconic phenomenon. Because the fire accident is a complex process containing many kinds of chemical reactions, there are many factors affecting its numerical simulation results (e.g. simulation time, etc.), such as the heat release rate per unit area of the fire source H, the combustion heat of the main combustible Q, and the thermal conductivity of the main building materials C. It is assumed that the heat release rate per unit area of the fire source H is unknown, and other parameters are known.

Step2 Linear Programming. Because the heat release rate per unit area of the fire source H is unknown, the relationship between it and the known variables $T, x_1, x_2, x_3, \cdots$ is utilized to derive the relationship equation as:

$$T = f(H, x_1, x_2, x_3, \cdots) \tag{42}$$

In the local region D, the fire development time node T is varied with the heat release rate H per unit area. Accordingly a local linearization of the functional relationship is performed and the equation is simplified as:

$$T = a \cdot H + b (a \neq 0) \tag{43}$$

Step3 Obtain the optimal solution based on large eddy simulation and least squares method. By reviewing the material, it can be determined that H is in the range of $[p,q]$. Take $H_1,H_2,H_3,H_4\cdots$ in this region, and use the numerical method to calculate $T_1,T_2,T_3,T_4\cdots$, and then combine with the method of least squares to determine the value of a,b. The linear relationship between H,T can be determined. The value of H' obtained from the calculation is substituted into the regional model D, and the simulation results (including the value of T') are obtained by numerical method.

Step4 Fire reconstruction based on optimal solution. Compare the burning time node T' in the region D with the time node T_0 in the field survey result in the numerical simulation result, if the values of T' and T_0 are approximately equal (within the allowable error), then the heat release rate of the fire source per unit area can be adopted H; if not, the above process is repeated until the optimal solution is obtained.

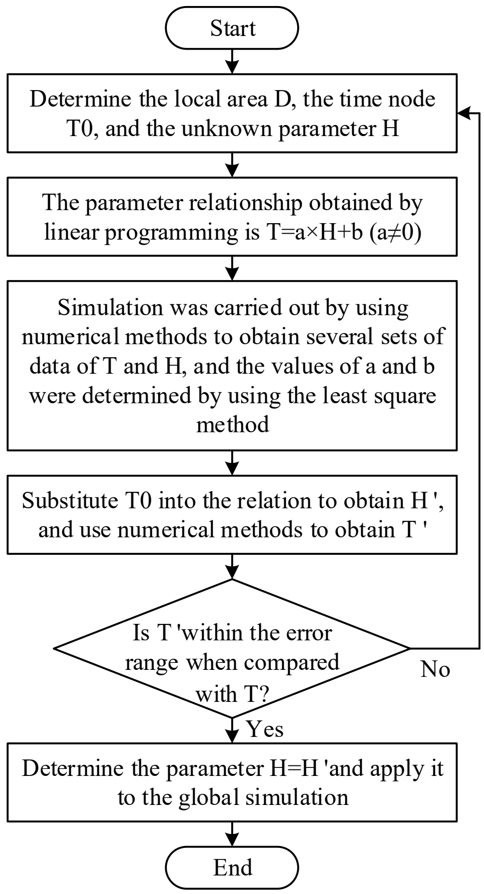


Figure 4: Flowchart of fire accident reproduction

III. B. 4) Related parameter settings

According to the real fire cases and various types of fire prevention measures (such as sprinkler systems, fire separation doors, smoke exhaust systems, etc.) failure of the fire most unfavorable principles, then the building 8 floor platform set the ignition source, according to the existing relevant research results, the fire model is usually selected non-steady state fire model $Q=\alpha t^2$, due to the selection of thermal insulation materials are mainly for the combustible and flammable materials, so that α selected ultra-rapid fire parameters 0.04674, ignition source is set as a steady-state fire source. Therefore, the α is selected as the ultra-rapid fire parameter 0.04674, and the ignition source is set to be a steady state fire source with a heat release rate of 5.5 MW. 8 to 38 floors of the façade are mainly set to be the common engineering materials, i.e., B2 combustible materials (wood, expanded polystyrene) and B3 flammable materials (polyvinyl chloride, polyethylene). The material parameters are selected as shown in Table 1, and the simulated combustion time is set according to the parameters of ignition temperature and heat release amount of various materials, which is about 1200s for wood, expanded polystyrene and polyvinyl chloride, and 800s for polyethylene.

Table 1: Material Values

Material	B2 Flammable material		B3 Flammable material	
	Wood	Foamed polystyrene	Polyvinyl chloride	Polyethylene
Density (kg/m³)	328.7	15.5	345.7	950.4
Specific heat capacity (kJ/kg·K)	1.25	1.08	1.01	1.02
Heat conductivity factor (W/(m·K))	0.12	0.13	0.09	0.12
Thermal radiation coefficient (W/ m·C)	0.93	0.93	0.93	0.93
Heat release (kW/m²)	165.7	146.3	176.4	1410.5
Ignition temperature (℃)	262.8	351.7	285.1	333.3

III. C. Fire spread simulation analysis

III. C. 1) Trends in heat release rates

The heat release rate is a parameter indicating the intensity of the fire, based on the fire simulation three-dimensional model given in the previous section and the fire reconstruction process, set the corresponding model parameters in Pyrosim software, and simulate the heat release rate of the whole combustion process as shown in Figure 5.

As can be seen from the figure, the heat release rate curve is in the form of a double peak. Before 120s belongs to the initial stage, 120~210s belongs to the rapid development stage, the polyurethane material burns rapidly at high temperature, and the 1st peak occurs at about 210s, when the heat release rate is $1.32*10^6$kW. Around 210~840s is the stable combustion stage, as the combustible materials in the room are ignited, the indoor and outdoor combustion together, and the 2nd peak occurs at around 840s, when the heat release rate reaches $2.15*10^6$kW. After 840s for the decline stage, after this time mainly by the B3 flammable materials polyvinyl chloride and polyethylene involved in the corresponding building combustion. Through the change curve of heat release rate, it can be combined with the high-rise building facade insulation materials to analyze the combustion situation, and provide effective data support for the development of reasonable and effective fire control measures.

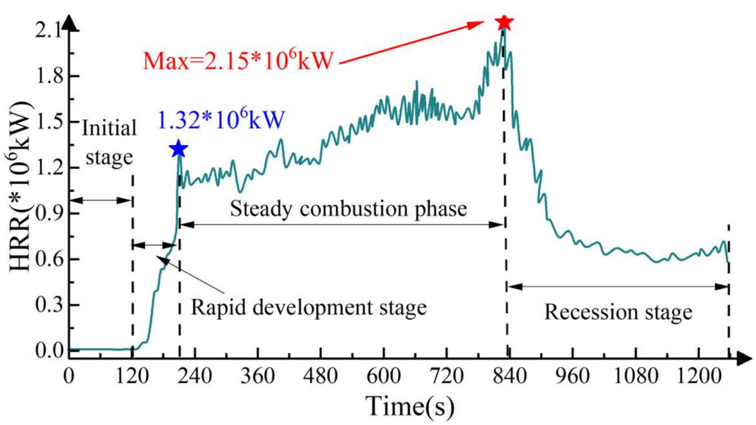


Figure 5: Heat release rate-time curve

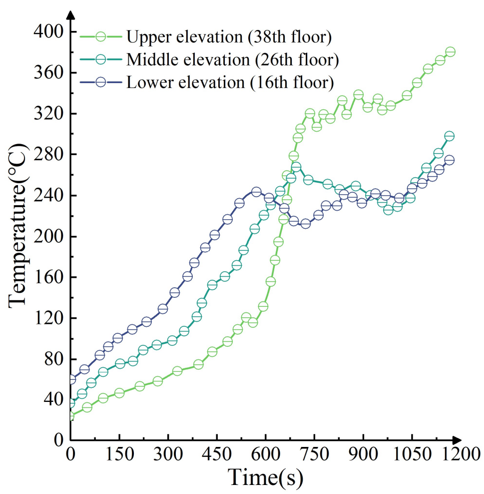
III. C. 2) Facade and interior temperature changes

(1) Temperature trend of the façade

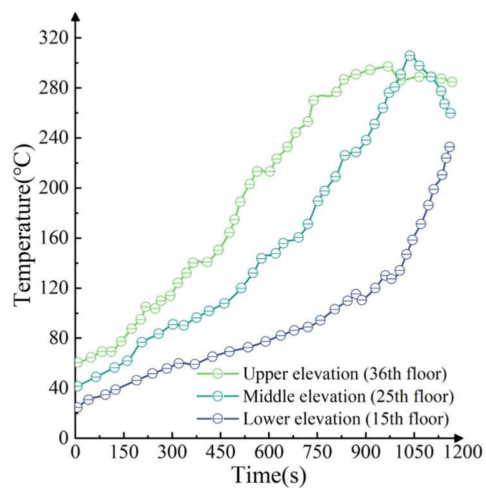
According to the temperature detector data obtained from the simulation, the facade as a whole is divided into three parts (8-18 floors for the lower part of the facade, 18-28 floors for the middle part of the facade, and 28-38 floors for the upper part of the facade) and the floors with the most drastic changes in each part are selected for the temperature comparison results as shown in Figure 6. Among them, Fig. 6(a)~(d) shows the temperature change curves of the facade of wood, expanded polystyrene, PVC and polyethylene, respectively.

As can be seen from the figure, the overall trend of temperature change of the façade constructed of B2 combustible materials such as wood and expanded polystyrene is relatively gentle, and the overall change of temperature of the façade constructed of B3 flammable materials such as polyethylene and PVC is more drastic. The temperature of the lower and middle part of the wood façade showed an increasing trend in the first 530s, rising to about 220℃~245℃, and then gradually became flat in the last 670s, and the temperature was 270℃~295℃ in 1200s. The temperature of the upper part changed most strongly, and the temperature increased to about 320℃ in the first 730s, and then it gradually increased slowly, and the temperature was about 380℃ in the 1200s. The temperature of the lower part of the expanded polystyrene facade changes most slowly, in the first 1000s it keeps a slow rise to 135℃, in 1200s it jumps to about 232℃, the middle and upper part are in the process of slow rise, the upper part is always higher than the middle part in the first 1050s, the middle part reaches the maximum value of 305℃ in the 1050s and then starts to fall, in 1200s it changes to 260℃, the upper part temperature changes to 285℃ in 1200s.

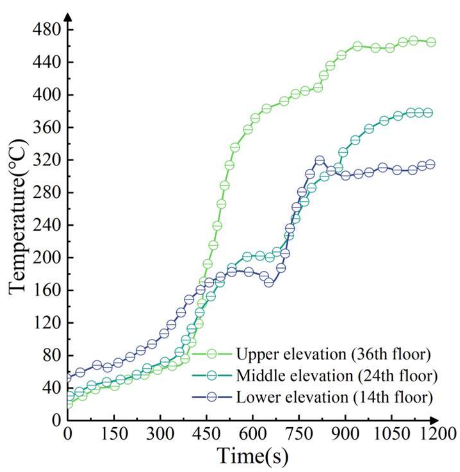
The lower and middle part of the PVC façade have basically the same trend of temperature change, showing an upward trend in the overall change process. The lower and middle temperatures increased to 315℃ and 378℃ at 1200s. The temperature change in the upper part is the strongest, and the temperature shows a rapid rising trend in the first 700s, rising to about 390℃, and then the temperature rises slowly until it rises to 465℃ in 1200s. The overall temperature change of the polyethylene façade shows a rapid rising trend, the temperature of the lower and middle part of the façade changes rapidly, in the first 690s the temperature of the lower part and the middle part were 1000 degrees and 800 degrees, but after 500s the temperature of the lower part and the middle part began to fall gradually, in 600s the temperature of the lower part and the middle part fell to 888 degrees and 695 degrees respectively. The temperature of the upper part of the façade has been in the state of rapid increase, and the temperature is lower than that of the center and the lower part in the first 640s, but the temperature continues to increase after 640s, and the temperature rises to about 1000℃ in 800s.



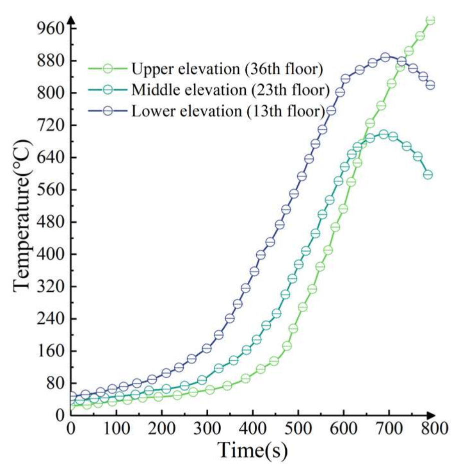
(a) Wood



(b) Foamed polystyrene



(c) Polyvinyl chloride



(d) Polyethylene

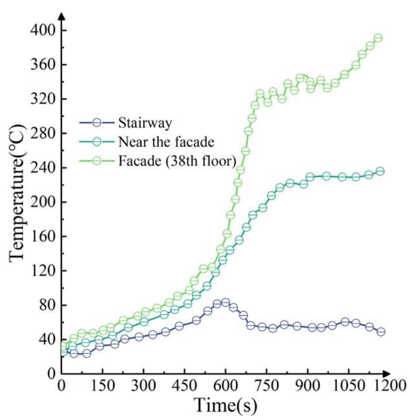
Figure 6: Temperature change curve of the facade of each material

(2) Indoor temperature change trend

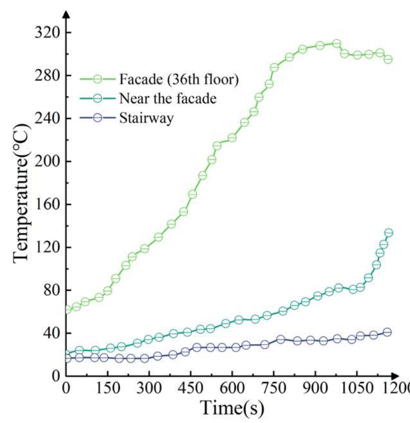
According to the most unfavorable principle of fire, the floors with the most drastic temperature changes are selected for the comparison of indoor temperatures, which are used to carry out the design of fire spread control strategies for high-rise building facade insulation materials. Figure 7 shows the indoor temperature change curves of different materials, of which Figures 7(a)~(d) show the indoor temperature change curves of wood, expanded polystyrene, PVC and polyethylene, respectively.

The indoor temperature change of B2 combustible materials (e.g., wood and expanded polystyrene) is not obvious, which can buy more time for fire spread and evacuation of people. When the facade is constructed with wood, the temperature of the room close to the facade rises to about 55℃ in 400s, reaching the critical value for human beings (lasting for 30min in <55° ambient), and it reaches 235℃ in 1200s. In this case, the temperature of the stairwell rises to 80℃ in 600s, which obviously exceeds the critical value of human beings, but due to the better gas circulation in the stairwell, the temperature drops to 80℃ again in 780s, and thus the temperature of the stairwell rises to 80℃ in 600s. However, due to the better air circulation in the stairwell, the temperature drops to 52℃ in 780s. When the façade is constructed with expanded polystyrene, the temperature of the room near the façade reaches the human body critical value of 55℃ only in about 750s, and the temperature rises to about 130℃ in 1200s, and the temperature of the stairwell stays below 40℃ in this case.

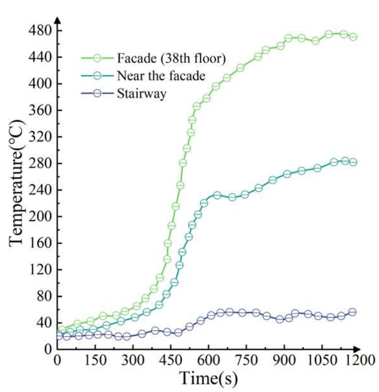
B3 flammable materials (e.g., PVC, polyethylene) room temperature changes significantly, compared with B2 combustible materials, is not conducive to fire spread control and evacuation. When the facade is constructed with polyvinyl chloride, the temperature of the room near the facade rises to 55℃ at 360s to reach the danger value for human body and still rises rapidly, and the temperature reaches 235℃ at 630s and continues to rise. The temperature in the stairwell increased to 55℃ at 680s to reach the human danger value, and then the temperature was maintained between 52~62℃. When the façade was constructed with polyethylene, the temperature in the room near the façade increased to 55℃ at 380s to reach the critical value for human body, and then the temperature continued to increase and reached 320℃ at 640s. The temperature in the stairwell reaches 55°C at 550s to reach the critical value for human body, and then it continues to rise to about 100°C at 800s.



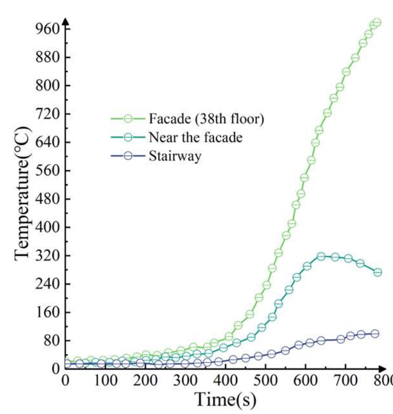
(a) Wood



(b) Foamed polystyrene



(c) Polyvinyl chloride



(d) Polyethylene

Figure 7: Temperature change curve of the facade of each material

According to the above simulation results for indoor rooms, stairwells and other areas, the temperature change in the indoor areas of the facades of the four materials basically shows a trend of first increasing and then gradually becoming flat. However, the time required for the indoor and stairwell temperatures to reach the human danger value of 55°C is different. When EPS is used in the façade of high-rise buildings, it can buy more time for evacuation and is more favorable for fire protection, while when polyethylene is used in the façade, the indoor and stairwell temperatures reach the hazardous value of 55°C at the earliest time, which is the most unfavorable for evacuation and fire protection.

III. C. 3) Trends in visibility over time

In order to further illustrate the effectiveness of high-rise buildings in the occurrence of fire to assist in the realization of personnel evacuation and fire spread control, this paper sets up four different types of fire conditions in the simulation process, as follows:

Scenario 1: The fire source is located in the first floor office lobby fire protection sub-area, the fire burning rate according to t^2 fire development, the fire growth coefficient is set to 0.048kW/s², in the automatic sprinkler system and smoke exhaust system are invalid, the fire maximum heat release rate of 3*10⁶kW.

Case 2: The fire source of this scenario is located in the first floor office lobby fire protection sub-area, the fire burning rate according to the t^2 fire development, the fire growth coefficient is set to 0.048kW/s², in the automatic sprinkler system failure, the maximum heat release rate of the fire is 3*10⁶kW, the smoke exhaust system is effective.

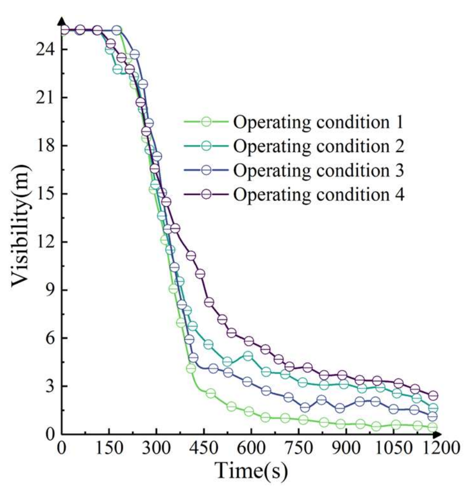
Case 3: The fire source of this scenario is located in the first floor of the office lobby fire protection sub-area, the fire burning rate according to the t^2 fire development, the fire growth coefficient is set to 0.048kW/s², in the automatic sprinkler system, the maximum heat release rate of the fire is 1.5*10⁶kW, the smoke exhaust system is ineffective.

Condition 4: The fire source of this scenario is located in the first floor office lobby fire protection sub-area, the fire burning speed according to t^2 fire development, the fire growth coefficient is set to 0.048kW/s², the automatic sprinkler system and the smoke exhaust system are effective, the maximum heat release rate of the fire is 1.5*10⁶kW.

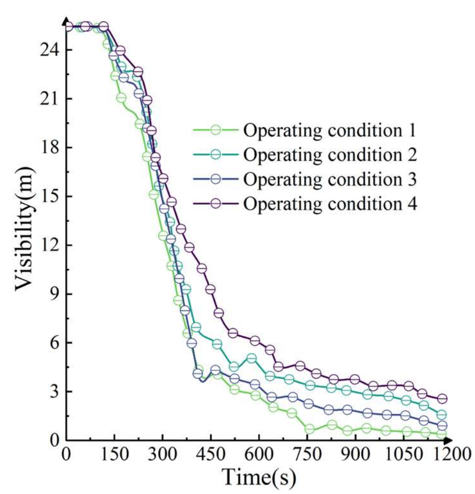
Based on the above four conditions, two measurement points (A and B) are set in the fire floor 38F, and two measurement points (C and D) are set in the first-floor lobby office area, and Fig. 8 shows the trend of visibility with simulation time obtained from four different fire conditions, where Figs. 8(a)~(d) are the visibility changes of the four measurement points, namely, A, B, C, and D, respectively.

To study the effect of visibility on fire spread control and safe evacuation of people when fire occurs in high-rise buildings with facade insulation material, it can be seen from the figure:

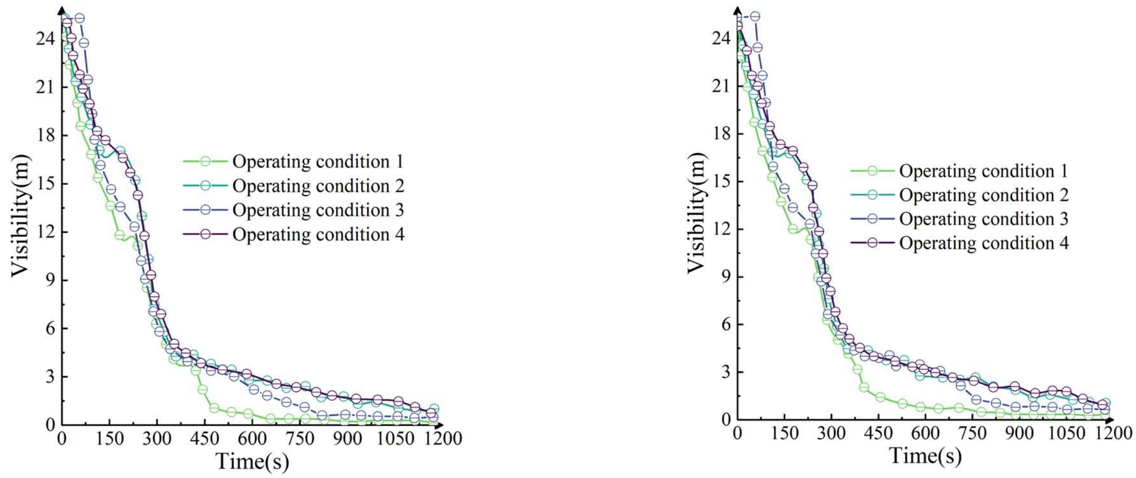
In the case of fire in the automatic sprinkler and smoke evacuation system all failure, each measurement point in about 450s has caused harm to the evacuation of personnel, at this time the visibility value are below 4m. Because the mechanical smoke exhaust can effectively exhaust most of the smoke, when the smoke exhaust system is open, it can effectively increase the visibility. Only in the case of effective automatic sprinkler system on the smoke visibility impact is not great, only to a small extent to increase visibility, the fire spread control and safe evacuation of people can not play a good role. In the case of automatic sprinkler and smoke evacuation system all effective, can largely improve visibility, can control the spread of fire and evacuation play a good role. Therefore, for high-rise buildings, the need to regularly check the effectiveness of automatic fire sprinkler and smoke evacuation system, so that in the event of a fire can be carried out in a timely manner to control the spread of fire, effectively realize the evacuation of personnel, reduce casualties due to high-rise building fires.



(a) Point A



(b) Point B



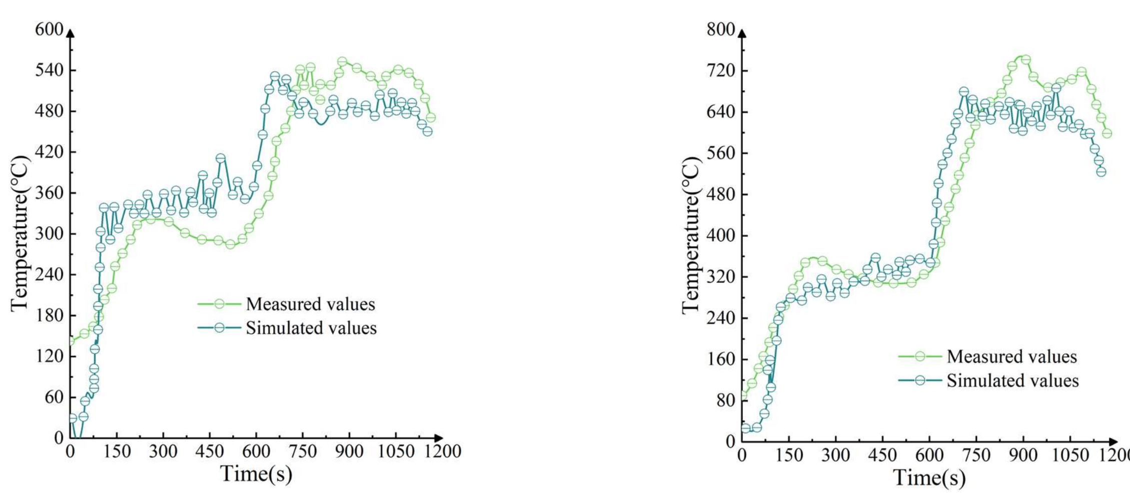
(c) Point C (d) Point D

Figure 8: Visibility follows the changing trend of time of simulation

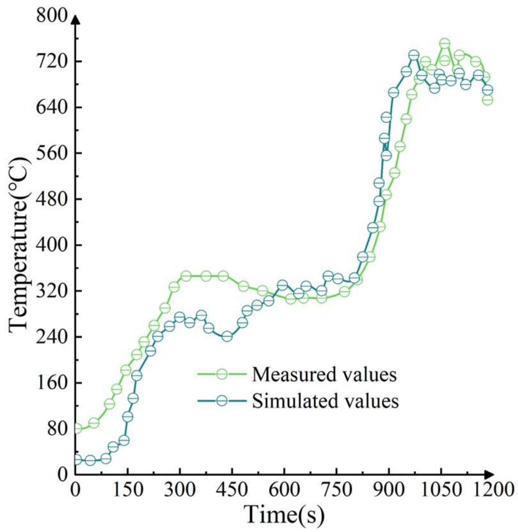
III. C. 4) Comparison of validity of simulation results

Based on the simulation model established in this paper for the fire spread of high-rise building facade insulation, the heat release rate, temperature change and visibility effects can be effectively clarified. In order to further verify the validity of the simulated calculated values, the data obtained from the four heat sensing galvanic couplings (TST1~TST4) of a certain floor room at the time of fire in the fire incident of the telecommunication building are used as the basis, and then the model of this paper is used to simulate the fire scene in this scenario. Following this, the temperature trends of the measured and simulated values at the time of fire are compared, and Fig. 9 shows the results of the comparison of the trends of the measured and simulated values of different thermal sensor couples, of which Fig. 9(a)~(d) are the results of the comparison of the temperature trends of TST1~TST4, respectively.

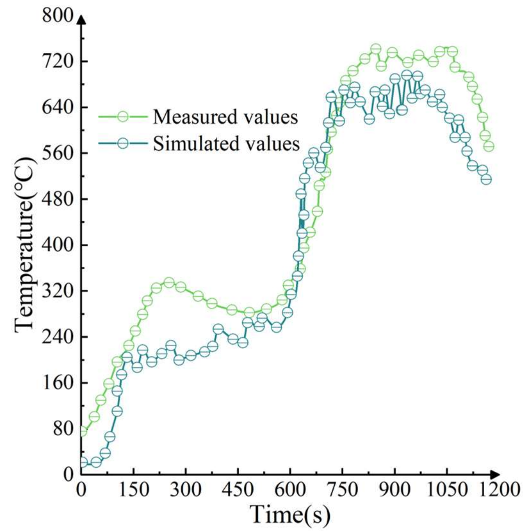
From the figure, it can be seen that although the simulation and test results in some temperature values there are large differences, but from the overall point of view, the two trends are consistent, so the use of Pyrosim software simulation of high-rise building facade insulation material fire spread of the change rule of the temperature has a certain degree of reasonableness. In order to facilitate the analysis and calculation, in the process of fire simulation, some reasonable simplification of certain conditions is made, which is the main reason for the error. Due to the fact that every real fire has a great deal of randomness, and the combustible materials are relatively complex, the computer simulation can not completely and accurately reproduce the actual development of the fire. Therefore, when comparing simulation and experimental results, it is not necessary to concentrate on the accuracy of individual values, but it is more important to grasp the development and spread of fire as a whole in the actual fire prevention and fire assessment process.



(a) TST1 (b) TST2



(c) TST3



(d) TST4

Figure 9: Changing trends between the measured values and the simulated values

III. D. Fire Spread Control Strategies

Based on the above simulation about the fire spreading process of high-rise building facade insulation material, this paper proposes the relevant control strategies when fire occurs in high-rise buildings from different perspectives, aiming to reduce the casualties due to high-rise building fires and minimize the economic losses based on the fires as much as possible.

III. D. 1) Enhanced mobilization of first mobilization forces

High-rise building exterior insulation system fire burning speed, building internal spread more ways, fire control, rescue difficulty. Therefore, the fire-fighting force scheduling should be in accordance with the plan to strengthen the first mobilization of forces, quickly assembled follow-up reinforcements, strengthen the superiority of the force for the fire, the adequate superiority of the force, excellent vehicles and equipment mobilized at the first time in the fire, for the smooth disposal of fire to provide reliable protection. Mobilization of fire-fighting forces, it is recommended for high-rise building characteristics, the timely mobilization of the appropriate height of the ladder trucks, high-spray trucks and crank trucks and other elevated vehicles, while mobilizing a large tanker fire trucks, compressed-air foam fire trucks and Class A foam trucks and other water supply vehicles, and the timely mobilization of smoke trucks, rescue vehicles and logistical vehicles and other reinforcements. It should be noted that the first to the field of commanders in the deployment of forces, to be in the high-rise building fire fighting surface side for the elevated vehicles reserved ample parking locations and operating sites, other vehicles shall not be occupied after the arrival of the field.

In addition, high-rise building exterior insulation system fire spreads rapidly, if not effectively controlled from the outside, the fire will first spread horizontally and vertically along the building exterior walls, through the blown window openings ignite combustible material quickly spread to the interior. At the same time, the high temperature droplets generated by the burning of external thermal insulation materials may form a new ignition point, so that the whole building in a short period of time to form internal and external connectivity, large-area three-dimensional combustion. Therefore, it is necessary to control and inhibit the spread of fire to the surrounding area as the primary task of external attack. It should be noted that when the fire point in the building and the height of the internal range of combat vehicles, and the neighboring window glass is not heat cracked, you can take the external attack to extinguish the fire. When the fire point in the building outside and neighboring window glass has been widely cracked, it is recommended to avoid external attack, the need to stay close to the fire building of the main combat fire trucks around a certain force to expand the alert range. And with the fire building to maintain a certain safety distance, to prevent flying fire, fire falling objects and “glass rain” and other secondary disasters caused by accidents.

III. D. 2) Development and use of flame-retardant external thermal insulation materials

One of the most basic strategies for fire prevention in exterior insulation buildings is to develop and use flame retardant or non-combustible exterior insulation materials, such as phenolic resin with flame retardant, smoke suppressant, foaming agent, curing agent and other additives made of phenolic foam insulation materials. Phenolic foam heat resistance is good, 30mm thick phenolic foam flat plate subjected to 1800 ℃ flame spray 15min, only the surface is slightly charred and will not be burned through, can effectively prevent the fire and the spread of fire. In fire accidents, most of the casualties are due to smoke and toxic gases caused by the fire scene, but phenolic foam even if ignited by high temperature, its combustion is no dripping material, low smoke, and almost no CO and other toxic gases. From the use of practice, phenolic foam insulation materials can play a safe and energy-saving “double insurance” effect. At the same time, drawing on the experience of developed countries, the development or revision of the corresponding norms and standards, phenolic foam as a public building standard flame retardant, combustion performance is lower than phenolic foam, is not allowed to use in public buildings. Despite the fire-retardant treatment, phenolic foam insulation materials are still organic materials, the use of oversized buildings should still be restricted, such as the building volume of more than 10,000m³ or a height of more than 35m of public buildings and residential buildings with a building height of more than 120m should be used inorganic thermal insulation materials such as rock wool, mineral wool, glass wool.

External insulation using combustible materials should take appropriate fire construction measures to prevent the spread of fire diffusion. External insulation using organic materials is the most serious danger of becoming a fire spreading and expanding the way, must take appropriate fire prevention construction measures to prevent the spread of fire diffusion. Exterior insulation should be used non-combustible materials to do horizontal and vertical separation, its width is not less than 1.2m, of which the area of combustible insulation between each isolation zone in public buildings should not be greater than 35m2, residential buildings in each isolation zone in the area of combustible insulation should not be greater than 60m2. building corners on both sides of the exterior wall and doorways, windows and other openings around the width of the non-combustible material should be used for a fee of not less than 0.8m width to Separation.

III. D. 3) Multi-point detection improves firefighting proactivity

Multi-point monitoring to enhance the initiative of fire emergency rescue is to break the waiting status quo of passively receiving emergency rescue calls, and change passive into active. By installing real-time fire monitoring and real-time alarm devices in the important streets and corresponding floors of the buildings in the areas under the control of each fire department, to enhance the initiative of the fire emergency rescue department to find fire hazards, and according to the fire hazard scene shown on the monitor, to quickly carry out rescue deployments and vehicle deployment, to seize the first opportunity to carry out fire-fighting and rescue.

In addition, to strengthen the use of public space in high-rise buildings to check, especially to strengthen the building corridors, staircases, as well as the occupation of the ground fire lanes to rectify the situation, and the implementation of regular tracking and inspection. For the occupation of public areas and special fire areas and not in accordance with the requirements of the rectification of the user to carry out warning education and impose appropriate penalties, so as to protect the fire emergency rescue public space is not illegally occupied.

Fire emergency rescue departments should try to unite scientific research institutes, design units, fire equipment production departments, on all kinds of buildings, especially high-rise buildings after the fire of toxic and hazardous gas emissions for scientific research and exploration. And gradually used in practice, improve its effectiveness, so as to reduce the degree of damage of toxic and hazardous gases for people's lives in the event of fire, and further enhance the effectiveness of emergency rescue.

IV. Conclusion

Based on the simulation results of the real fire case in the telecommunication building, the article analyzes the fire spread, the temperature change of the façade and the room, and the visibility change of the façade in the case of different materials, and obtains the following conclusions:

(1) For high-rise building façade fire, during the whole fire process, the temperature change is mainly concentrated in the external façade and near the façade room and other areas, while the temperature spread of the indoor stairwells and other parts is not very obvious.

(2) In a high-rise facade fire, visibility changes compared with temperature changes, visibility reaches the critical value of the human body faster, and has a greater impact on the evacuation of people.

(3) Compared with B2 combustible material and B3 flammable material in fire simulation, B3 flammable material has the most drastic flame change and the most rapid temperature change.

(4) The facade fire prevention and control measures use flame retardant or non-combustible materials for facade insulation, and fire separation zones are set up between the insulation layers and in the vertical direction to reduce the fire damage that may occur. And there is a need to further carry out multi-point monitoring as a way to enhance the fire rescue initiative.

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