Calculation Method of Spatial Equilibrium Coefficient for Land Expansion of High Density Building Complex

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Abstract. The existing calculation methods have the problem of fuzzy characteristics of equilibrium coefficient, which leads to too many iterations in the calculation process. Combined with the normal force climbing effect, the shear stress of the rise and fall angle of the high density building group is obtained. Extract the mathematical characteristics of the equilibrium coefficient based on the space sharing theory, quantify the index data, calculate the equilibrium coefficient of the high density building group, and realize the calculation method design. Experimental results: under the same experimental conditions, the approximate number of iterations of this design method and the existing two calculation methods is 10 ~ 25 times less than the other two calculation methods, which proves that the performance of this design method is better.

1. Introduction
The purpose of the development of high density buildings is mainly to ease the tension of urban land space and give full play to the role of urban planning. Under the basic national conditions of "more people and less land" in China, in order to ensure economic development, ensure food security and protect the ecological environment, we must control and guide the expansion process of urban construction land, promote the efficient use of urban construction land, and improve the quality of urbanization development and the sustainable level of social and economic development. Delimitation of urban development boundary not only helps to guide the further agglomeration of urban construction land, control the unlimited expansion of cities, prevent urban diseases and overload of regional resources and environment, but also promotes the coordination and integration of urban and rural planning and land use planning, and promotes land intensive use and urban compact development. Foreign scholars have different understanding of the definition of expansion space [1]. In 1980, the comprehensive environmental response, compensation and Liability Act issued by the United States began to study the treatment and liability of urban abandoned and underutilized industrial land, or known or suspected polluted land. Although the term "inefficient land" is not used, the phenomenon of "inefficient land" has attracted the attention of the government. Inefficient land use refers to the real estate that contains or may contain hazardous substances, pollutants or pollutants and makes expansion, redevelopment or reuse complicated. After that, for the convenience of their own research, each department in the United States defined inefficient land use [2]. The United States Environmental Protection Agency (EPA) defines inefficient land use as the land that is complicated to
be redeveloped and reused due to the existence of real or potential environmental pollution. The research on the expansion space of high-density buildings in the United States focuses on the industrial land with pollutants. In the United Kingdom, inefficient land refers to the land that has been used, is now idle, abandoned or underutilized. The expansion space defined in the United Kingdom is not only industrial land, but also not necessarily contaminated land. It focuses on the land that has been used and is currently idle.

In recent decades, domestic scholars put forward the concept of inefficient land use, and began to study a series of problems related to it. In the existing research, most of the scholars in our country mainly focus on the benefit distribution and the balance layout of the expansion space when carrying out the old city reconstruction. In China, due to the need of land development, some coastal cities have studied the old city reconstruction scheme earlier. At present, there are few studies on the land use of high-density buildings in China, but we can refer to the research on land intensive use [3]. In the aspect of intensive use of development zones, some scholars study the influencing factors, and think that the main factors affecting the intensive use of land are the level of economic development, industrial policy and land use structure. In addition, some examples are used to demonstrate the action mode of these factors. In the aspect of the construction of the evaluation method of industrial land intensive use, some scholars use the mathematical method to carry on the evaluation research from the construction of new mathematical function. Scholars have conducted relevant research on index selection, mainly from the influencing factors, and demonstrated the rationality of index selection by using examples [4]. There are also some scholars who have made innovations from the theoretical methods used in the research. The academic research on the calculation method of the spatial equilibrium coefficient of high density building group land expansion is not very rich and needs to be further discussed.

2. Calculation method of spatial equilibrium coefficient for land expansion of high density building complex

2.1. Obtaining the shear stress of the rise and fall angle of high density buildings

In recent years, as an indispensable part of the city, high-density buildings should interact with the city more actively to create a more suitable space environment. Many contemporary buildings are constantly exploring and practicing high-density public buildings, and more possibilities of expanding space[5]. When the structural plane of a building is affected by the shear force, the expression formula of the critical equation is as follows:

\[ E = l \cdot \tan \alpha + b \cdot l \]  (1)

In formula (1), \( l \) is the friction angle in the structural plane of the building, \( b \) is the shear force in the structure, and \( \alpha \) is the normal pressure of the building. The principle of shear stress is shown in Figure 1:

![Fig. 1 Principle of shear stress action](image)

It can be seen from Figure 1 that with the increase of shear times, the smaller the normal stress is, the higher the cross coincidence degree of tangential normal displacement curve is. With the increase of cyclic shear times of structural plane, the wear degree of structural plane in each shear process
becomes lower and lower\textsuperscript{[6]}. Under the same normal stress, the change trend of cyclic shear normal displacement and tangential displacement curves of structural plane with different relief angles is basically the same. The main difference is that the smaller the undulation angle is, the higher the coincidence rate of tangential displacement normal displacement curve is, which indicates that the larger the angle of structural plane is, the more serious the structural plane wear is in the process of shearing. Based on this, the steps to obtain the shear stress of the rise and fall angle of high density buildings are completed.

2.2. Extracting mathematical characteristics of equilibrium coefficient based on spatial sharing theory
In the evaluation of land use efficiency, the value range, dimension and unit of equilibrium coefficient will vary greatly with the nature of equilibrium coefficient, so these index values are not directly comparable. Therefore, it is necessary to standardize the equilibrium coefficient, so that all the index data can be converted into a unified measurement value, and on this basis, the mathematical characteristics of the equilibrium coefficient can be extracted\textsuperscript{[7]}. The mathematical expression formula of equilibrium coefficient is as follows:

\[ q \cdot r^{i+1} = q(d, k, d_e) \quad (2) \]

In formula (2), \( q \) is the dynamic function, \( i \) is the discrete coefficient, \( k \) is the local mapping coefficient, and \( e \) is the dimension of the land expansion space of the building complex. Theoretically speaking, in the extended space, the set of spatial nodes distributed by the equilibrium coefficient has only one form for one-dimensional space partition, while multi-dimensional equilibrium coefficient may have multiple forms. The expansion space can be divided by Euclidean space rules of any dimension, and the equilibrium coefficient of expansion space used in the simulation of construction land expansion space is usually two-dimensional. Neighborhood is the related element adjacent to the coefficient under certain rules in the extended space. The equilibrium coefficient of different dimensions can be defined in different ways.

2.3. Calculation of spatial equilibrium coefficient of high density building group land expansion
Equilibrium coefficient is a method to analyze and calculate slope stability. This method is mainly aimed at slope stability analysis with broken line sliding surface. In actual engineering calculation, because the width of the strip divided by landslide is small enough, the sliding surface of each strip can be approximately a straight line, that is, the transfer coefficient method can be used for research\textsuperscript{[8]}. At the same time, because the solution of equilibrium coefficient pair is an explicit solution process, it has strong applicability in practical engineering, and the calculation steps are relatively simple. In the process of calculation, it is assumed that the soil particles are completely saturated by incompressible liquid and affected by seepage\textsuperscript{[9]}. The soil particles can be divided into two parts, the skeleton formed by coarse particles and the fine particles which can move under the influence of seepage. On the basis of the above, the formula for calculating the increase rate of soil particle mass inside the construction land is as follows:

\[ M = \frac{\rho \gamma \cdot h}{\gamma' \cdot u} \quad (3) \]

In formula (3), \( \gamma \) is the fine particle size of the soil, \( \rho \) is the density of the sediment affected by the liquid flow, \( h \) is the change range of the internal density of the soil, and \( u \) is the quality of the soil. On the basis of formula (3), the two-dimensional form of the mass increasing rate of soil particles is as follows:

\[ M = \frac{\rho \gamma \cdot h}{\gamma' \cdot u} + \frac{\rho \gamma \cdot h_n}{\gamma' \cdot j} \quad (4) \]

In formula (4), \( j \) is the actual mass of soil in the process of migration, \( n \) is the velocity of fluid infiltration, and the meaning of other variables is the same as that in formula (3). After the two-
dimensional expression formula is obtained, the component seepage velocity index of equilibrium coefficient in horizontal and vertical directions is obtained, the specific expression is as follows:

\[
\begin{align*}
T_{x_1} &= \rho \gamma \cdot y_x \\
T_{x_2} &= \rho \gamma \cdot y_y
\end{align*}
\]  (5)

In formula (5), \(x_1, x_2\) represents the vertical and horizontal hydraulic conductivity of the soil, \(\gamma\) represents the fine particle size of the soil, and \(y\) represents the seepage velocity vector of the soil. On the basis of formula (3) ~ (5), the calculation formula of the spatial equilibrium coefficient of high density building group land expansion is as follows:

\[
\sigma = \frac{D \cdot G + Q_m}{A_\eta} \]  (6)

In formula (6), \(D\) is the building density of high-density buildings, \(G\) is the building coefficient of industrial land, \(Q\) is the idle rate of land, \(m\) is the average output intensity, \(A\) is the vector value of equilibrium coefficient, and \(\eta\) is the structural plane strength of buildings. According to the different seepage velocity, some fine particles in the soil will be eroded and migrated due to the influence of seepage. Meanwhile, some fine particles may deposit due to the influence of liquid flow in the process of fine particle migration. On the contrary, the effect of seepage on coarse particles in soil can be ignored. In the study of soil seepage affected by particle migration, the erosion, migration and deposition of fine particles in soil can not be ignored. Based on the above calculation, the calculation steps of spatial equilibrium coefficient of high density building group land expansion are completed.

3. Experimental analysis
In order to test the effectiveness of the calculation method, an experimental test is carried out.

3.1. Getting the experimental data
Taking X city as the research object to calculate the spatial equilibrium coefficient of high-density building group land expansion, according to the research data, the land expansion data of this city in ten years is shown in Table 1:

| year | Expansion area (h/m²) | Expansion speed (h/m²) | Expansion strength (%) | Expanded contribution rate (%) |
|------|-----------------------|------------------------|------------------------|-----------------------------|
| 1    | 1120.33               | 120.34                 | 16.34                  | 6.334                       |
| 2    | 768.42                | 136.18                 | 17.11                  | 8.491                       |
| 3    | 647.64                | 244.39                 | 18.42                  | 6.558                       |
| 4    | 1013.54               | 137.24                 | 20.13                  | 10.102                      |
| 5    | 778.69                | 203.48                 | 18.22                  | 7.164                       |
| 6    | 1036.11               | 168.77                 | 21.11                  | 9.878                       |
| 7    | 689.55                | 128.56                 | 16.45                  | 7.203                       |
| 8    | 843.16                | 188.34                 | 17.48                  | 8.362                       |
| 9    | 735.19                | 210.17                 | 18.02                  | 9.454                       |
| 10   | 840.36                | 349.01                 | 16.44                  | 8.373                       |

Based on the above extended data of X city, the experimental test is carried out.

3.2. Experimental result
Two existing calculation methods of equilibrium coefficient are selected and compared with the calculation method of this design. Under different building densities, the number of iterations of the
calculation method is less, which proves that the performance of the calculation method is better. The experimental results are shown in Figure 2-4:

As can be seen from Figure 2, the approximate values of the iteration times of this design and the existing two calculation methods are 10.5, 20 and 30 respectively; As can be seen from Figure 3, the approximate values of the iteration times of this design and the existing two calculation methods are 20, 50 and 50 respectively; As can be seen from Figure 4, the approximate values of the iteration times of this design and the existing two calculation methods are 80, 90 and 95 respectively; It is proved that the calculation method of equilibrium coefficient in this design has less iterations and better performance in practical application.

4. Conclusion
The calculation method of equilibrium coefficient in this design has been proved to have better performance than the existing calculation method by experimental test. To a certain extent, it promotes the development of the whole construction field, and lays a theoretical and practical foundation for scholars from all walks of life to carry out relevant research. At the same time, the relationship between population data and building density is described, which can effectively realize the coordinated development of multiple fields. Due to my limited ability, the generality of the article is not comprehensive enough, and will continue to improve in the future.
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