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Retraction

Retracted: Electrochemical Preparation of Recycled Self-Compacting Concrete Composite Beams and Their Application in Prefabricated Buildings

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] Y. Yuan and Y. Zhu, "Electrochemical Preparation of Recycled Self-Compacting Concrete Composite Beams and Their Application in Prefabricated Buildings," *Journal of Chemistry*, vol. 2022, Article ID 4748456, 8 pages, 2022.

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Research Article

Electrochemical Preparation of Recycled Self-Compacting Concrete Composite Beams and Their Application in Prefabricated Buildings

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In order to solve the problems of electrochemical preparation of recycled self-compacting concrete composite beams and their application in prefabricated buildings, we need to meet the requirements of national housing industrialization and green buildings, make up for the low development capacity of prefabricated buildings, and improve the speed of housing construction and the rapid development of the construction industry. Now the prefabricated building has entered a period of rapid growth. However, the research on the construction technology of the prefabricated building is still in its infancy, and there are many difficulties and challenges in the construction. The deformation and internal force of a prefabricated residential laminated floor slab in the construction process of prestressed PK slab transportation, stacking, hoisting, and the laminated cast-in-situ layer will affect the normal use of the building. However, at present, there is less mechanical analysis of its construction process, so there is blindness in the formulation, implementation, and inspection of the construction scheme. Through the social survey of 200 people, 179 people believe that prefabricated buildings will be better than traditional buildings. Therefore, by participating in the practice of prefabricated housing engineering, the key mechanical problems in the construction of the composite floor slab of prefabricated housing are explored and found.

1. Introduction

In China, for a long time, frame structure, frame shear wall structure, shear wall structure, steel-concrete structure, and other concrete buildings mainly adopt the traditional construction method of the on-site binding beam, slab, and column reinforcement pouring concrete. The degree of industrialization is low, the product rate of building structural components is low, the quality of building residential products is poor and unstable, the labor production efficiency is poor, the design and construction is extensive, the loss of building materials is large, and the amount of construction waste is large. In the past ten years, China's scientific research work on prefabricated concrete buildings has gradually increased. A number of enterprises have cooperated with scientific research institutions such as colleges and universities to carry out mechanical analysis and related technical research and applied it in development projects, which has been demonstrated on a certain scale [1]. Compared with the cast-in-situ concrete buildings constructed by traditional construction methods, the construction process of prefabricated concrete buildings has the advantages of saving resources, small on-site operation, improving on-site construction conditions, convenient construction, and so on. In the construction process, the transportation and hoisting process of the prestressed PK plate are relatively convenient and feasible. The prestressed PK plate laminated floor does not need formwork, which effectively reduces the amount of formwork, reduces the amount of work on the construction site, shortens the construction period, saves materials, and reduces the project cost [2].

Due to the variability of the concrete tensile strength, with the increase in stress in the component, there will be one or several cracks in the weak part of concrete at the same time. At the same time, the tension on the crack section will no longer be borne by the concrete but by the reinforcement. The stress of the reinforcement at the crack will suddenly increase, and the concrete at the crack will retract to both sides. At the same time, the slip and bonding stress between the reinforcement and the concrete will appear [3]. The function of bond stress is to transfer the tensile part of the reinforcement to the concrete until the distance from the crack increases, the strain of concrete and reinforcement gradually becomes equal, and the bond force is zero. With the continuous increase in the external load, new cracks will appear in concrete members and the stress between reinforcement and concrete will also change with the change in distance from cracks. Among them, the stress variation diagram of reinforcement and concrete of axial stressed members is shown in Figure 1.

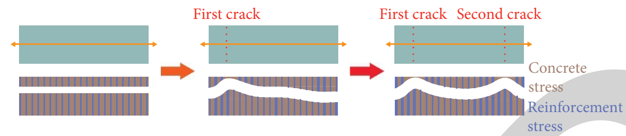

Figure 1: Axial stressed member.

2. Literature Review

Ihsan et al. said that in the early 1960s [4], the former Soviet Union used the assembled integral concrete laminated floor in the floor of buildings. Its structural structure is to use the prefabricated flat ribbed and grooveless prestressed concrete thin plate as the formwork, use manual rough treatment on the upper surface of the prestressed concrete thin plate, and then pour ceramsite concrete on the prestressed concrete thin plate. Its strength is generally C7.5~C10. The artificial rough surface treatment on the upper surface of the prestressed concrete sheet ensures the combination of precast slab concrete and cast-in-situ concrete. Wu et al. said that the assembled integral concrete composite floor has been successfully applied in the seismic building engineering in the southern region of the former Soviet Union [5]. Huang et al. of France widely used the assembled monolithic concrete composite floor from 1970 to 1979 and configured reinforcement on the composite section to bear the shear force of the composite section so as to make the precast slab and cast-in-situ concrete work better together [6]. In recent years, Wender et al. studied and developed a new type of the reinforced concrete structure system, that is, semi-precast structure system. Its structure is to place the *U*-shaped semi-precast beam on the *I*-shaped semi-precast column and connect the lower reinforcement [7]. Yang et al. reported that PC laminated floors are widely used in the floors of public industrial buildings and multistorey and high-rise buildings [8]. According to the research, Imaz-Lueje et al. believed that the PC laminated floor can be applied in seismic areas and strong seismic areas [9]. Li et al. said that the FP laminated floor slab is a form of the PC laminated slab, and its structural structure is the prefabricated thin plate with high strength and low relaxation female thread reinforcement. The prefabricated thin plate is not only a part of the FP laminated floor slab structure but also a template for the construction of the cast-in-situ concrete layer. The FP laminated floor slab can be formed by pouring concrete on its prefabricated thin plate [10]. In 1961, Bodehou et al. studied and manufactured the assembled integral multi-ribbed floor slab. The beam adopts the prefabricated "I" shaped small beam, and the precast concrete thin plate is placed on the beam. The precast concrete thin plate and the beam are poured with concrete to form a whole after curing, and the precast thin plate is placed on the flange at the lower part of the beam as the ceiling flat roof [11]. The Beijing Civil Aviation Office Building and the Beijing National Hotel are the first two high-rise buildings with assembled integral concrete composite structure in China.

3. Method

3.1. Failure Criteria of Concrete. The failure criterion of concrete is very important in the finite element analysis of reinforced concrete structures. The failure of concrete materials is defined by the use of ultimate strength. The ultimate strength of concrete has a variety of strength criteria with different parameters, such as one to five parameters. At present, the Willam–Warnke five-parameter strength criterion model is often used in finite element analysis. The meridian of the model is a more general tension and compression parabolic meridian [12].

The failure surface expression of the Willam–Warnke five-parameter failure criterion is shown as follows:

$$\frac{F}{f_c} - S \geq 0. \tag{1}$$

When the Willam–Warnke five-parameter model is used for finite element analysis, the concrete failure surface is continuous and convex without an inflection point and the failure surface is nonlinear on the meridian plane. The model analysis results are consistent with the experimental data. The parameters in the failure criterion of the model can be determined by standard tests. Therefore, the Willam–Warnke five-parameter model can better describe the failure characteristics of concrete [13]. The meridian equations of pressure and tension are shown in formulas (2) and (3):

$$\frac{\tau m1}{fc} = a0 + a1\left(\frac{\sigma m}{fc}\right) + a2\left(\frac{\sigma m}{fc}\right)^2, \tag{2}$$

$$\frac{\tau m1}{fc} = b0 + b1\left(\frac{\sigma m}{fc}\right) + b2\left(\frac{\sigma m}{fc}\right)^2. \tag{3}$$

The pull meridian and the pressure meridian intersect on the hydrostatic pressure coordinate axis. In the aforementioned formula, only five parameters are independent. The five parameters are determined through the material test [14].

The basic premise of elastoplastic analysis of concrete is to determine the stress-strain relationship. In the case of multiaxial stress, due to the limitation of test conditions, the stress-strain relationship of concrete is often simulated and determined by the equivalent uniaxial stress-strain relationship. The full curve of concrete under uniaxial compression and uniaxial tension is obtained by the test [15]. The stress-strain relationship of concrete under uniaxial compression is shown in Figure 2, and the stress-strain relationship of concrete under uniaxial tension is shown in Figure 3.

The Hognestad formula and the Saenz formula are often used in the stress-strain curve of concrete under uniaxial compression. The Hognestad formula is often used in specifications, and the Saenz formula is often used in finite element analysis. The following is the expression of the Saenz formula, as shown in formulas (4)–(6):

$$\sigma = \frac{E0\varepsilon}{1 + (a + (E0/ES) - 2)(\varepsilon/\varepsilon0) - (2a - 1)(\varepsilon/\varepsilon0)^2 + a(\varepsilon/\varepsilon0)^3}, \tag{4}$$

$$a = \frac{(E0/Es)((\sigma0/\sigma N) - 1)}{((\varepsilon N/\varepsilon0) - 1)^2} - \frac{\varepsilon N}{\varepsilon0}, \tag{5}$$

$$Es = \frac{\sigma0}{\varepsilon0}. \tag{6}$$

In finite element analysis, the stress-strain curve of reinforcement is often simplified. When the reinforcement has an obvious yield point, the ideal elastic-plastic model is generally adopted, and the mathematical expression is shown in the following formulas:

$$\sigma = E\varepsilon, \tag{7}$$

$$\sigma = f_y. \tag{8}$$

When the reinforcement does not have the obvious yield point, the broken line model is generally adopted, which has two slopes (elastic slope and plastic slope). The mathematical expression is shown as follows:

$$\sigma = E\varepsilon. \tag{9}$$

3.2. Treatment of Prestressed Reinforcement. The stress characteristics of the structure change due to the application of prestress. In the process of structural deformation, the stress of prestressed reinforcement also changes all the time, which makes the restraint effect on the structure also change. Therefore, the basis of prestressed concrete structure analysis is to accurately grasp the treatment method of the prestressed reinforcement [16]. There are two methods in ANSYS.

3.2.1. Equivalent Load Method. The effect of the prestressed reinforcement on the structure is simplified into an equivalent external load applied to the structure. The equivalent load method is mainly used in relatively simple structural analysis. This processing method can meet the accuracy requirements of engineering and is widely used. Because it does not need to consider the position of reinforcement, the model is simple and the calculation process is easy to converge, but there is no way to analyze the internal force of reinforcement and its influence on concrete deformation and internal force. It is difficult to consider the influence of the synergistic effect of the prestressed reinforcement and the external load on the concrete deformation and internal force, and there is no way to analyze the influence of the external load on the stress increment of prestressed reinforcement [17].

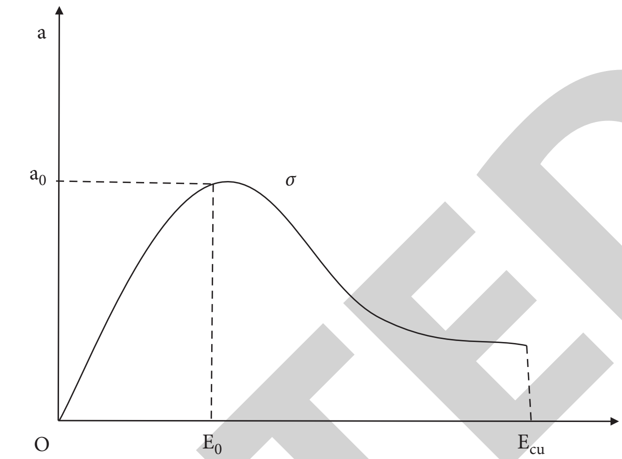

Figure 2: Stress-strain relationship of concrete under uniaxial compression.

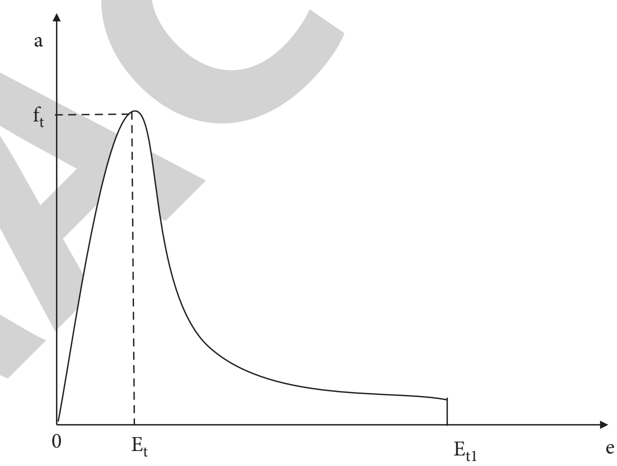

Figure 3: Stress-strain relationship of concrete under uniaxial tension.

3.2.2. Solid Reinforcement Method. In the process of establishing the model, the concrete adopts the solid element and the prestressed reinforcement adopts the link element, which makes the influence of reinforcement and concrete in the model to be considered at the same time. The solid reinforcement method can consider the influence of several factors and can be applied to the analysis of complex structures. It can also be used when engineering analysis needs high accuracy. There are two main methods to apply prestress in model analysis: one is the initial strain method, and the other is the temperature reduction method. The initial strain method is to set an initial strain for the prestressed reinforcement to replace the effect of prestress, and the two functions are the same. The cooling method is to cool the rod element link and shrink the rod element link to apply prestress in this way [18].

Compared with the initial strain method, the cooling method is simple, and the influence of many factors can be considered, such as stress loss and stress increment of the external load on the prestressed reinforcement. In the model, the prestress is applied by the cooling method, and the temperature change value corresponding to the prestress value needs to be calculated in advance, as shown in the following formula:

$$\Delta T = \sigma lEa. \tag{10}$$

In the convergence criterion of ANSYS, the relative measure of convergence based on displacement and the absolute measure of convergence based on force are given. It is better to use the force or moment as the basis of convergence tolerance in the process of model analysis. Element size, convergence criterion, and substeps are three main factors affecting the convergence of the SOLID65 element. In the process of establishing the model, the elements should be divided appropriately. If the element division is too small, the calculation may be unable to continue due to stress concentration. Hexahedral elements should be used as much as possible. When setting the convergence criteria, the convergence conditions can be relaxed appropriately. Generally, it should not exceed 5% and the force based convergence conditions are adopted [19].

Generally, when the crushing of concrete is not considered in the model calculation, it is easy to converge in the calculation. If the normal structure or the member is calculated and analyzed, the uniaxial compressive strength uncompst should be set to −1, and the option of concrete crushing should be turned off. "Concr + miso" shall be used when calculating the limit of the analyzed structure or member, and the crushing inspection of concrete shall be closed. In the process of modeling, to avoid the failure of solution due to the damage of concrete caused by stress concentration, it is advisable to appropriately increase the element size near the support or add some elastic cushion blocks or change the element at the support to solid45 and give steel properties so as to avoid stress concentration. The Solid45 unit provided by ANSYS is similar to the SOLID65 solid unit. The Solid45 unit has no cracking and crushing performance.

From the current test of composite beams in the world, the final deformation characteristics and crack development of composite beams under the concentrated load are very close to those of general cast-in-place beams. It is also shown that there are mainly vertical cracks in the middle of the beam span, and the spacing distribution is basically the same; there are obvious inclined cracks near the supports at both ends. Finally, the inclined cracks pass through the composite surface until the beam is damaged. However, due to the secondary pouring and two-stage stress of this structural member, its development process is different from that of general cast-in-place beams. When the first load is applied, the section of the precast part of the beam presents a distribution similar to that of the oblique crack of the abdominal shear: it is distributed as many thin and short vertical cracks, but the width of the crack is small, the extension height of the crack is small, and there is no oblique crack. After the load is applied in the second stage after superposition until the beam is damaged, its crack is called the critical oblique crack and after many experimental studies conducted by scholars, it is found that the critical oblique crack is always along the connecting line between the load action point and the bearing cushion block [20].

The crack development process of the composite beam is different from that of the cast-in-place beam, which is mainly caused by its two-stage construction and two-stage stress. When the composite beam is stressed f for the first time, the prefabricated part is compressed on the upper side and tensioned on the lower side. At this time, the compressive stress is generated on the upper side of the prefabricated part, that is, the composite surface. When the composite beam is formed, the compressive stress on the composite surface is solidified by the postcast part. For the later load of the whole composite beam, this part of the compressive stress is equivalent to prestress, so scholars vividly call it "load prestress." When the composite beam is stressed F1 for the second time, with the continuous increase in F, the stress state on the composite surface will change from compression to tension. In the process of mutual offset between tensile stress and load preload, the internal force on the composite surface will be redistributed until the load prestress disappears. Therefore, the load prestress inhibits the deformation of concrete and reinforcement so that when the inclined crack develops near the superposition surface, the speed becomes slow and even stagnates, which delays the main inclined crack from passing through the superposition surface, resulting in the crushing and destruction of the concrete in the shear compression area of the inclined section, thus improving the shear bearing capacity of the beam [21].

The two-stage stress characteristics of composite beam also determine that the stress distribution on its section is different from that of the cast-in-place beam. Under the action of F, because the height of the prefabricated part is relatively low compared with the overall beam, the phenomenon of "normal stress advance" of longitudinal reinforcement and "shear stress advance" of the stirrup will appear under the same external load, which is also the reason for the early occurrence of cracks in the composite beam. After the postcast concrete reaches its design strength, it begins to bear external forces. Under the action of $F2$, the concrete stress of the laminated layer starts from zero, so there is a phenomenon of "shear stress lag." The stress of the precast concrete is quite complex. Some of the original stress on its section and the stress caused by F offset each other and some overlap each other. With the increase in the number and length of inclined cracks, the stress on the section is constantly redistributed. When the inclined cracks approach the superposition surface, they develop slowly and stagnate when they reach the superposition surface. In this way, the influence of the load applied in the first stage on the precast part is weakened. At this time, all the loads on the beam are gradually borne by the whole beam and the whole deformation pattern of the composite beam is gradually close to that of the general cast-in-place beam until it is finally damaged.

To sum up, the phenomena of "load prestress" and "shear stress lag" are beneficial to composite beams and we should pay attention to and make rational use of them. For the early and rapid crack development caused by "stress lead" and "shear lead," we should take appropriate measures in design and structure to reduce or avoid as much as possible.

The development pattern of the cracks in the composite beam is basically consistent with the research of scholars: because of the characteristics of the double stress of the composite beam, the cracks appear earlier and the earlier cracks are caused by the stress in one stage; the cracks in the precast part are mainly vertical cracks, with a small width and small height of crack extension. Compared with the whole cast-in-place beam, the stress of the composite beam remains unchanged in the first stage. When the whole bears the same load, vertical cracks appear at the supports of the composite beam and the whole cast-in-place beam. The cracks at the supports of the composite beam develop faster than that of the whole cast-in-place beam, and inclined cracks appear faster. However, the inclined cracks of the composite beam develop more intensively and roughly develop into two main inclined cracks, which connect the load and the bearing cushion block. However, the inclined cracks of the whole cast-in-place beam developed from the support are scattered and random. In the midspan part, "load prestress" makes the development of cracks in the composite beam slow with the increase in load and the development of cracks in the midspan of the whole cast-in-place beam is almost synchronous with the inclined cracks. Generally speaking, the cracks of composite beams appear earlier than those of cast-in-place beams, which are disadvantageous in the normal use stage of components, but their cracks develop slowly and have their advantages in the limit use stage [22].

The reason for the slow development of cracks near the composite surface of the bending area in the midspan of the composite beam is as follows: the load preloading stress is generated at the composite surface due to the loading in the first stage. When the second stage force is applied, the stress redistribution occurs on the composite surface, that is, from the compression area to the tensile area. At this time, the load preloading stress and tensile stress offset each other with the increase in the load and the cracks in the midspan do not begin to develop again until the tensile stress gradually offsets the load preloading stress. Therefore, the development of midspan cracks in the crack development process of composite beams is relatively slow, which is the so-called "compression stress lag" phenomenon, so it has a good inhibitory effect on the crack development of composite beams.

In the simulation, it is also found that the crack development speed at the support of the composite beam is faster than that of the cast-in-place beam, which is due to the lower height of the prefabricated part of the composite beam without support (compared with the cast-in-place beam). The construction load generated in the construction stage is borne by this part, so there is an obvious phenomenon of "shear stress advance" in the stirrup in the precast part of the composite beam, and the stress of the same stirrup in the cast-in-place part (composite layer) is "shear stress lag" compared with the stirrup in the same position of the whole cast-in-place beam.

According to the crack development characteristics and the development mechanism of composite beam components under normal use, some influencing factors of crack development of the composite beam are explained. Then, the cracks of the composite beam and the whole beam are simulated and compared by ANSYS finite element software. The simulation results are consistent with the theory, which proves that the cracks of composite beam can be studied by ANSYS. By simulating the effects of several main parameters αh and aM affecting the composite beam and the concrete grade difference between the precast part and the composite part on "load prestress," "stress advance," and "stress lag," then, we analyze and study its advantages and disadvantages on crack development. Through comparative analysis, it can be seen that in order to control the height of the precast part and the size of the one-stage load, the concrete strength of the precast part and the composite beam and the difference between the two parts of concrete should be controlled, which can be paid attention to in the design and engineering of the composite beam. The change in the concrete strength of the precast layer is shown in Table 1, and the list of the concrete strength change in the cast-in-situ layer is shown in Table 2.

Stress analysis is mainly used to determine the stress concentration and peak stress and strain at the dangerous point related to component failure. It is very necessary to analyze the location selection of fabricated joints. The maximum compressive stress under the action of seismic force is used to judge how to select the segment position [23]. The variation of unit stress is shown in Figure 4.

4. Results and Analysis

The composite beam has the advantages of convenient construction of the prefabricated structure, short construction period, integrity of cast-in-situ structure, and good seismic performance, which makes it widely used in engineering construction. On the contrary, its two-stage pouring and two-stage stress make the mechanical performance and deformation pattern of the composite structure different from those of the whole pouring structure [24].

Based on the in-depth research theory of composite beams by many scholars, the numerical simulation of reinforced concrete composite beams under the concentrated load is carried out by using ANSYS large-scale finite

Table 1: Change in the concrete strength of the precast layer.

Concrete strength of the cast-in-situ layer	C30	C30	C30	C30
Concrete strength of the precast layer	C25	C30	C40	C50

Table 2: List of concrete strength changes in the cast-in-situ layer.

Concrete strength of the cast-in-situ layer	C25	C30	C25	C40
Concrete strength of the precast layer	C30	C30	C30	C30

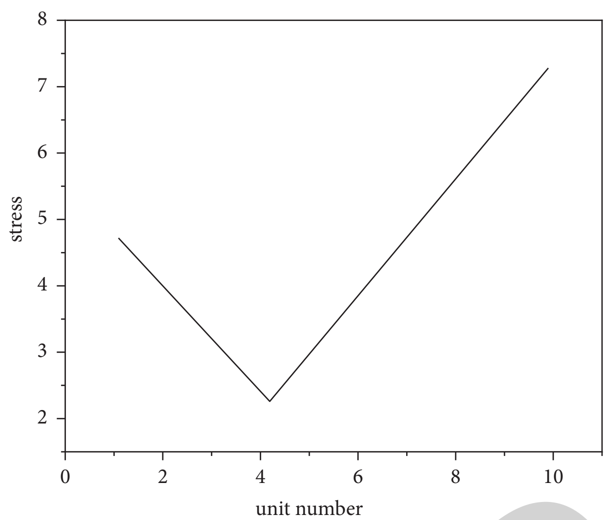

Figure 4: Variation of unit stress.

element software. The influential laws of these factors on the generation and development of component cracks and deflections are summarized by in-depth analysis of the stress changes in longitudinal reinforcement, stirrups, and concrete caused by superposition parameters α_h and a_{gy}, and the strength grade of old and new concrete. Then, through the analysis of the simulated deflection value and influencing factors, the relationship between the above factors and the deflection value of the composite beam are fitted. It can be concluded as follows: in order to prevent excessive deflection in one stage from affecting the normal use of composite beams in the later stage, the height of prefabricated parts in the design and construction of composite beams should be controlled. The size of the stage load, and the use of new and old concrete grade composite beam should be considered [25].

On the basis of the crack development mechanism of the composite beam and the simulation results of the normal composite beam by ANSYS [26], it is proved that the cracks of composite beams can be studied by ANSYS. Through the simulation of several main parameters α and α affecting the composite beam and the impact analysis of the concrete grade difference between the precast part and the composite part on "load prestress," "stress advance," and "stress lag," it can be seen that the height of the precast part and the size of the first stage load should be controlled. At the same time, the difference of concrete strength between the precast part and composite part should be controlled, and attention should be paid to the design and engineering of the composite beam to control the speed of crack development [27].

Through the comparison of deflection values, it is proved that the simulation of displacement and deformation of the composite beam by ANSYS is accurate and it is also concluded that the influencing factors affecting the stiffness and deflection of the composite beam are mainly the strength of the stressed reinforcement, precast part, and cast-in-situ part of concrete [28]. The deflection value and influencing factors obtained from the simulation are analyzed, and the relationship between the superposition parameters αh and aM and the concrete strength of the precast part and the superposition part on the deflection value of the composite beam are fitted. During the design and construction of the composite beam, it must be noted that the height of the precast part cannot be too small, which is generally taken as 0.55–0.6 and the load in the first stage should not be too large. These two cases are mainly to prevent the excessive deflection in the first stage from affecting the normal use of the composite beam in the later stage. In addition, the old and new concrete of the composite beam shall not be of the same grade as far as possible because both theoretical and simulation results tell us that when the concrete of the same grade is used, the deflection of the composite beam is relatively large.

5. Conclusion

By comparing the results of ANSYS finite element simulation analysis with the theoretical calculation results of the reverse arch value and the detection test results of the detection center, it is proved that the ANSYS finite element analysis model is reasonable and feasible.

In the mechanical simulation analysis of the prestressed PK slab composite floor construction process, the simplification of the finite element analysis model has a great impact on the simulation results. The two skids under the bottom plate of the prestressed PK plate are simplified into linear fixed support and linear sliding support, respectively, and two special lifting appliances are simplified into linear sliding support, four ordinary lifting points are simplified into four-point sliding support, and two temporary supports are simplified into linear sliding support, which makes the simulation analysis results closer to the actual situation. Through experiments, it is proved that the electrochemical preparation of the recycled self-compacting concrete composite beam and its application in prefabricated buildings are feasible, which effectively solves the requirements of national housing industrialization and green buildings, makes up for the lack of low development power of prefabricated buildings, and improves the construction speed of the construction industry and the rapid development of the construction industry.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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