Structural characteristics and form analysis of taxiway bridge in military airport

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Abstract: The scale of modern airport continues to expand, considering the needs of future use of multiple aircraft types and models, in order to improve the relevant design and planning of taxiways in the current military airport, it is necessary to consider the structure of airport taxiways and Bridges. According to the experience of the civil airport taxi road and bridge construction, the paper analyzes the military airfield taxiing bridge structural characteristics and load characteristic, proposed for use in military airfield taxiing bridge structure form, the slide to the width of the bridge, span layout, section forms, high beam and the size, the details for the military airport taxi provides the reference for the simulation modeling and the analysis of internal force of bridge.

1. Introduction
With the improvement of China’s comprehensive national strength, military airports have changed the use of aircraft from a single aircraft type and single aircraft type to multiple aircraft types and types. The number of aircraft keeps increasing and the scale of airports continues to expand. In the future, multi-aircraft support bases and comprehensive support bases [1] will be built to improve the comprehensive support capacity of airports. Compared with ordinary military airports, the support capacity of comprehensive support bases has been greatly improved, and the number of support aircraft and vehicles will also increase exponentially. It is inevitable that multiple runways and taxiways will be built. Considering the taxiway dispatching use of military airports, the operation of airport support vehicles, the entry and exit of support personnel and other airport operation conditions, it is necessary to consider the construction of airport taxiway bridge to improve the airport dispatching capacity.

Civil airports have been built and use taxi roads and Bridges. Domestic and foreign airport taxi roads and Bridges are mostly built in hub airports, such as guangzhou baiyun international airport, Beijing capital international airport, Shanghai pudong international airport, Kennedy airport and Pearson airport [2]. At present, in the field of military airfield, the research of airfield taxi bridge is still blank. This paper refers to the existing design scheme of civil aviation airport, analyzes the load characteristics of military aircraft, combined with the actual needs of comprehensive support base, presents the structural characteristics analysis and structural form analysis of military airport taxi road bridge, and provides a basis for the future design of military airport taxi road bridge

2. Structure and load characteristics of sliding bridge
Civilian large hub airports have use sliding road and bridge construction, but the taxi hasn't a special code for the design of bridge design, the current general reference when design "highway bridge design general specification" (JTG nikon D60-2015) [3], the "highway reinforced concrete and prestressed
Concrete bridge and culvert design specifications (JTG. 3362-2018) [4] specification, such as the limit state design method. At present, the military airport taxi hasn’t been used in actual construction bridge precedent, nor can it be in accordance with the standard specification, the reference design for civil aviation airport taxi bridge method, after comprehensive analysis of military aircraft models associated with the selected typical design models, and USES the typical aircraft quality as the design load, maximum glide for military airfield taxiing mechanical analysis of bridge, and analyze the other typical model checking, to ensure the rationality of structure design.

2.1 Structural characteristic analysis

Civil airport taxi road bridge application is mostly located in the airport internal taxiway and urban road three-dimensional intersection location, military airport taxi road bridge will be used in the future for multiple types of military support base, therefore, the design of taxi road bridge should not only meet the needs of design safety rationality, but also meet the relevant economic requirements. In general, the stress members of civil engineering related structures, including bridge structures, are mainly tensile, compressive and bending. At present, the application in the design of highway bridge more for prefabricated reinforced concrete beam bridge, more than ordinary city bridge design adopts prestressed concrete continuous girder bridge, reinforced concrete and prestressed concrete girder bridge adopt concrete compressive materials as the main, set according to different needs of reinforced or prestressed concrete, prestressed concrete girder bridge camber improve mechanical performance can be designed. There are two design ideas of airport taxi road bridge. The first method divides the deck system of airport taxi road bridge longitudinally into several independent Bridges, which is to simplify the design form of taxi road bridge under the condition of allowable safety degree, and adopt the traditional highway bridge design method after conversion of aircraft load. This method can reduce the transverse connection of sliding bridge, increase the control internal force, increase the height of beam body and occupy the clearance under the bridge. The second method is the transverse integral structural system. The cross-section of the deck system of the airport taxi road bridge is the integral section. The construction method is the integral cast-in-situ. This method is complex in calculation and analysis, and requires higher construction requirements. However, with the increase of transverse connection, the reduction of control internal force and the reduction of beam height, the safety degree is improved and it is more economical and reasonable. T beam and other structural forms have little transverse connection, and the design structure under the action of aircraft load will have the situation that the beam height is too high, therefore, the airport taxi road bridge mostly adopts box girder. Due to the characteristics of aircraft load concentration, the design of box girder also needs to consider the economic applicability, according to the sliding road bridge load distribution and stress characteristics of the configuration of prestressed steel and ordinary reinforcement, box girder side can be reasonably designed with flange plate, to make the distribution of internal force uniform.

2.2 Load characteristic analysis

Military aircraft calculation parameters [5]- [6] mainly involve main landing gear configuration, main landing gear load distribution coefficient, number of main wheels, main wheel tire pressure and single wheel load, etc. In this paper, typical military aircraft A, B, C, D and E are selected as structural analysis models of taxiway bridge in military airport, and the dynamic load distributed by A single wheel on the main landing gear of the aircraft (when the nose landing gear bears the load) is used as the design load, as shown in equation (1).

\[ P = \frac{G K_k K_{d}}{MN} \]  

Where, G is the maximum take-off gravity of aircraft, kN. Kz main landing gear load distribution coefficient, %. Kd is the coefficient of interaction between aircraft power and lift force. When the designed aircraft tire pressure \( q > 1.08 \text{ mpa} \), \( K_d = 1.25 \). When \( q < 1.08 \text{ mpa} \), \( K_d = 1.20 \), and \( K_d = 1.0 \) in the middle of runway. M is the number of main landing gear. N is the number of wheels on a single main landing gear.
The design loads of main landing gear and nose landing gear are calculated as shown in table 1.

Table 1  Single wheel design loads for main landing gear and nose landing gear

| The plane mode | Maximum take-off gravity (kN) | Load distribution coefficient of main landing gear (%) | Coefficient of interaction between force and lift | Main landing gear single wheel design load (kN) | Front landing gear single wheel design load (kN) |
|----------------|-------------------------------|------------------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Type A         | 597.8                         | 95.0                                                 | 1.20                                          | 85.64                                         | 17.93                                         |
| Type B         | 742.8                         | 92.5                                                 | 1.20                                          | 103.07                                        | 33.42                                         |
| Type C         | 1754.0                        | 92.2                                                 | 1.20                                          | 161.74                                        | 40.04                                         |
| Type D         | 1862.0                        | 94.0                                                 | 1.20                                          | 131.27                                        | 33.52                                         |
| Type E         | 372.4                         | 90.0                                                 | 1.25                                          | 209.47                                        | 46.55                                         |

3. Analysis of structure form of taxi bridge in military airfield

3.1 Wide to determine

Compared with ordinary highway and urban bridge, airport taxi road bridge is most special in that the load of aircraft is larger and the function is concentrated compared with that of automobile. In terms of the choice of structure form, the taxi road bridge of military airport should meet the relevant requirements of the safe operation of all kinds of military aircraft.

In theory, planes can taxi anywhere in the safe area of an airport taxiway. For this reason, the FAA recommends that the width of the taxiway bridge cover the entire flat area of the taxiway bridge, not just the width of the taxiway. According to this proposal, the width of the taxi bridge should be no less than the wingspan of the representative aircraft, resulting in a significant increase in the cost of the taxi bridge. Considering that the plane mainly glides along the middle line of the bridge and passes through the taxiway bridge, there is less load bias, so the width of the taxiway bridge should be reduced as far as possible to ensure the safe operation of the aircraft.

Reference the domestic civil aviation airport taxi bridge civil airport airfield technology standard "(MH5001-2013) specified in [7]" glide slide bridge width should be no less than bridge straight line section of the road surface and the minimum width of shoulder, set the full load bearing width less than the width of the road pavement and shoulder always, you should use the positive effective way to limit the plane lateral migration. The side-movement restriction facilities shall be located at the edge of the taxiway bridge to prevent the aircraft from sliding out of the taxiway bridge and shall not damage the aircraft ".According to the relevant provisions of this standard, the width of sliding road bridge is generally the width of road surface and road shoulder. According to the relevant classification standards of taxiway widths of military airports, taxiway widths of secondary airports are 14~16m, shoulder width is 1m, third-level airports are 16~18m and shoulder width is 1~3m.

The design of military airfield bridge typical aircraft main landing gear spacing, wingspan, and refer to the common bridge design method and the width of bridge construction experience. Military airfield taxiing bridge width is given priority to with standard military airport taxiway width, slightly bigger than the taxiway width to ensure safety. The principles of bridge width can be meet the aircraft main landing gear edge of the lateral slide and bridge the minimum clear distance requirements.

Standard taxiway widths for aircraft with typical loads in military airports and taxiway widths of typical aircraft are shown in table 2.

Table 2  Width of standard taxiway in different military aircraft

| The plane mode | Type A | Type B | Type C | Type D | Type R |
|----------------|--------|--------|--------|--------|--------|
| Standard taxiway width (m) | 16     | 16     | 18     | 18     | 14     |
| Width required on the taxiway bridge (m) | 13.7   | 15.7   | 16.2   | 17.8   | 10.2   |

The first type of base mainly supports multiple types of aircraft. The applicable types are mainly fighters, but also bombers and medium transport planes. Referring to the standard width of sliding road bridge of typical load models, the width of base taxiway is 14~16m, the width of sliding shoulder is 1m, considering the width of taxiway, the width of sliding road bridge is at least 16m, the optimal is
18m. Considering the influence of auxiliary facilities and lower supporting structure of a base sliding road bridge, the design width of a base sliding road bridge is proposed to be 20m.

The second type of base is mainly comprehensive support base, suitable for all military aircraft. Referring to the standard width of taxiway bridge of typical load model, the second-class base taxiway adopts the third-class military airport taxiway width of 16~18m, the shoulder width of taxi is 1~3m, considering the width of taxiway, the width of airport taxiway bridge is at least 18m, the optimal is 24m. Considering the ancillary facilities and lower supporting structure of the second type base sliding road bridge, the design width of the second type base sliding road bridge is proposed to be 25m.

3.2 Span layout analysis
In terms of the layout of taxi road and bridge spans at military airports, traffic operation under taxi road and bridge at military airports and special vehicle operation requirements are taken into account. According to highway route design specification (JTG d20-2006) [8] and relevant specifications of military airports, the taxi road and bridge spans at military airports are formulated.

At present, the traffic flow of military airport road traffic lines is not very large. According to the existing road standards, ordinary two-way two lanes can be met. But taxi bridge considering the future heterogenous base for security and comprehensive security, use aircraft type, quantity is big, more appropriate security vehicle type and quantity also dramatically increased, scale and scope of base has greatly increased, compared with the existing airport taxi bridge road and bridge crossing situation is more complex, the taxi operation more bridge bridge, traffic is increased.

Reference design for bridge construction experience and slide related to civil aviation airport road and bridge design, draw up slide design bridge bridge traffic lines appropriate for four lanes, the standard width of 3.75 m/lanes, set the shoulder to 1.0 ~ 2.5 m, total taxi traffic line bridge bridge pavement width should be 17 ~ 20 m (according to the actual need to access the corresponding road shoulder width), for a moment considered to 20 m.

According to above analysis, and finally determined that a slide base 20 m span bridge design, bridge 20 m wide, second base slide design bridge span 20 m, 25 m wide, military airfield design of bridge deck are one-way slide, slide at the same time two types of bridge deck are common driving motor vehicles for military airport, related to military airfield bridge, wide span bridge design parameters are shown in table 3.

| Table 3 | Specifications of taxiing bridge |
|---------|----------------------------------|
| Applicable base type | The first base | The second base |
| The sliding bridge is wide | 20 m | 25 m |
| Sliding bridge span | 20 m | 20 m |

3.3 Sectional formal analysis
Domestic highway and city Bridges, mostly USES the box section [9], draw lessons from the general practice in civil airport taxi bridge at the same time, considering the military aircraft related characteristic and the particularity of military airport related construction, this article glide bridge with simply supported box girder structure, cross section form choose single box section, the design characteristics of this bridge form into mechanical characteristics related to the construction is relatively convenient, clear and economical. Because the design span of the military airfield taxi road bridge is small, the single span simply supported box girder can meet the requirement of relevant span.

The designed span of the first and second base sliding road Bridges is 20m, and there is no need to set box girders to adapt to the change of bending moment of the coordinated structure. The whole sliding road Bridges in military airports adopt box girders with equal section, which can meet the requirements of relevant forces. The reasonable setting of beam height can make the internal forces reach the relevant bearing standards. The uniform section structure is neat in appearance, which can save materials and simplify the construction. The whole cast-in-place construction or prefabricated beam construction can be used, which is beneficial to the construction of military airport base.
Military airfield taxiing bridge design method and the general city, highway Bridges is roughly same, slide in bridge self-respect and related ancillary facilities of dead load effect, the airport within relevant cars and military aircraft loads, the influence of live load need adjustment slide set high beam makes bridge girder bending moment in loading Angle coordinate reasonable and economical.

Due to military airfield taxiing bridge structure comparison and bridge span are smaller, wide variety of models function makes the form of load more special, slide design military airport road and bridge when considering the weight and structure of the overall need to reduce concrete, high reference civil aviation taxiway bridge and ordinary reinforced concrete prestressed bridge girder is high, as the analysis of relevant resources, consulting relevant military airport design experts and bridge after the expert opinion, involved in this paper, two types of military airfield taxiing preliminary selection of beam bridge is 1.6 m high, with one box girder are multicellular box section, according to the different categories base wide set appropriate box number, The width of each chamber is 2.5m.See figures 1 and 2.

3.4 Detail size plan
The main function of the web of box girder is to bear the normal bending stress and torsion shear stress of the structure. The minimum thickness of web should take into account the arrangement of prestressed cables and the needs of concrete pouring. If some steel cables are anchored to web, the requirement of local stress under anchor should also be considered. Generally, the web thickness is gradually widened from the middle span to the fulcrum to bear the larger shear force at the fulcrum of the beam. Generally, the web thickness is 300–800mm, but it also reaches nearly 1m. In this paper, 0.5m was used for the middle web and 0.5m for the side web in the multi-compartment segmentation.

The top and bottom of box girder mainly bear the positive and negative bending moment of the structure. When the full bracket construction method is adopted, the lower edge of the beam, especially the section near the pier, will bear great compressive stress. The bottom plate of box section should gradually increase its thickness to the top of pier with the increase of negative bending moment of box girder to meet the requirements of compression. Two factors are generally considered in determining the thickness of roof of box section: one is to meet the requirements of transverse bending moment of bridge panel. The second is to meet the requirements of arranging longitudinal and transverse prestressed steel bundles. In reinforced concrete bridge panels, the general roof design is 20–40cm, the bottom plate is 20–30cm, there is a certain relationship between the thickness of roof and bottom plate and the spacing between webs, and the thickness of roof and bottom plate can be reduced correspondingly when the webs are large. In this paper, the thickness of roof and bottom plate is 0.28m and 0.25m respectively.

It is necessary to set a support at the joint of roof and web. The bearing improves the bending and torsional stiffness of the section and reduces the torsional shear stress. The bearing can absorb the negative bending moment at the fulcrum of the bridge panel, thus reducing the positive mid-span bending moment of the bridge panel. In addition, the bearing eases the stress transition of the box girder, which can avoid the stress concentration and reduce the secondary stress. Considering from the structure, the longitudinal and transverse prestressed tendons can be arranged in the space provided by them, which can guarantee the thickness reduction of roof and floor.

Generally, the ratio of supporting height to width at the roof is 1:3, 2:1, 1:1, etc. The supporting aspect ratio at the bottom plate is 1:1, 2:1–3, 1:3. In this design, the contact support size of roof and web is 80mm × 17mm, and the contact support size of bottom plate and web is 50mm × 20mm. The main section dimensions of box girder are shown in figure 1 and 2.

![Figure 1. Cross-section size of class I base sliding road bridge (unit: cm)](image-url)
The main cross section properties of the cross section of the designed box girder for type I and type II sliding road bridges are shown in Table 4.

Table 4  Cross section properties table

| Category | Area (m²) | $A_{xy}$ (m²) | $A_{xz}$ (m²) | $I_{xx}$ (m^4) | $I_{yy}$ (m^4) | $I_{zz}$ (m^4) | Outside the perimeter (m) | Inside the perimeter (m) |
|----------|-----------|---------------|---------------|----------------|----------------|----------------|---------------------------|--------------------------|
| A        | 15.08     | 10.26         | 4.32          | 17.98          | 5.16           | 4.85          | 42.71                     | 28.62                    |
| B        | 20.74     | 16.32         | 0.84          | 24.47          | 6.83           | 5.15          | 51.59                     | 40.56                    |

4. Conclusion
This paper analyzes the structural characteristics of taxiway bridge in military airfield and the loading characteristics of military aircraft. Based on the general design specifications of highway bridges and culverts, combined with the practical needs of two kinds of support bases, the structural forms such as bridge width, span, section property and detail size of sliding road bridges of multi-machine support bases and comprehensive support bases are presented respectively. It provides the basis for simulation modeling and scheme design of taxi bridge in military airport.

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