DOI: 10.23977/ieim.2022.051006
ISSN 2522-6924 Vol. 5 Num. 10

Study on Site Selection Range of High Plateau Civil Airport Based on Atmospheric Pressure Data Analysis

Liu Zhiheng[1,a], He Yao[1,b], Yang Le[2,c]

[1]*CACC Southwest Design and Research Institute Co. Ltd, Chengdu, China*
[2]*China Academy of Civil Aviation Science and Technology, Beijing, China*
[a]*tsliuzhiheng@126.com*, [b]*heyaocd@126.com*, [c]*yangle@mail.castc.org.cn*

Keywords: data analysis, atmospheric pressure, airport site selection, pressure altitude, airworthiness

Abstract: In China's Tibet and other high plateau areas, most of the low altitude areas and relatively good clearance conditions are basic farmland or urban areas, while the number of airports in Tibet is relatively small, which has greatly restricted China's civil aviation transportation. Therefore, it is an important issue for the airport construction site selection in Tibet at this stage whether the site selection limit of the airport elevation not exceeding 4420m can be broken. This paper first introduces the current situation of site selection in high altitude areas of Tibet , Atmospheric pressure of High Plateau Airport and analyzes the airworthiness of aircraft. Then, the conversion relations among air pressure, air pressure altitude and airport elevation are analyzed. After that, a case study was conducted on a site in Tibet, which verified that when the airport elevation exceeded 4420m, the site could still meet the requirements of aircraft approval envelope. Finally, the impact of atmospheric pressure data on the site selection range of high plateau civil airport is summarized and suggestions are put forward.

1. Introduction

The ultra-high altitude areas in the country are mainly concentrated in Tibet. The airport density in Tibet is low, and there is an urgent need for airport layout. However, there are objective constraints, so it is necessary and targeted to study. Therefore, we take Tibet as the regional object of study. At present, according to the requirements of relevant documents, the elevation above sea level of the newly built or relocated civil transport airport shall not exceed 4420m. However, Tibet has a unique geographical environment. The average altitude is high and the terrain fluctuates greatly. 90% elevation above sea level of the whole area is above 4000m, and the territory area above 4420m exceeds 70%. Most of the remaining low-altitude areas are located in the non-actual control area of Nyingchi, the Hengduan Mountain Area of Changdu and the lower reaches of the Yarlung Zangbo river. Most of the low-altitude areas are river valleys, no matter the Yajiang river valley or the Hengduan Mountain Valley, Its flight and construction conditions are very poor. From many aspects, if the site selection is continued in the area below 4420m above sea level, the optional area is very small, and the site selection is very difficult, and the surrounding terrain is complex. In order to meet the requirements of safe operation of civil aviation, a large amount of funds will be invested in ground leveling and Mountain cutting, resulting in poor economic efficiency of airport construction and reduced feasibility of approval. As for the ultra-high altitude area above 4420m, the surrounding clearance conditions are very good and the vision is wide. From the ground and clearance conditions, it is more suitable for the airport site selection. If a breakthrough can be found through the analysis of meteorological data and a scientific and appropriate standard for aircraft airworthiness can be found, the site selection in Tibet will usher in a new space. On the contrary, it will face a situation of few feasible sites, large investment and poor approval. Therefore, it is necessary to carry out the study on site selection range of high plateau civil airport based on atmospheric pressure data analysis and break through the limitation that the altitude of newly built or relocated civil transport airports should not exceed 4420m.

At present, there are few studies on high altitude airports, especially ultra-high altitude airports at home and abroad. Zhang Li'an discussed the characteristics and design of Plateau and high plateau airports[1]. Wang Kun analyzed the site selection conditions of high plateau airport from three aspects: meteorological conditions, aircraft performance analysis and navigation signal coverage [2]. Pei Zhao and others made a preliminary study on the problems related to the development from the aspects of the characteristics and difficulties of the construction of high altitude airport, the human resources of the operation guarantee of high plateau airport, and the facilities and equipment of high plateau airport [3]. Li Ting studied the influencing factors and methods of airport site selection on High Plateau [4]. However, the above studies have not broken through the limitation that the altitude of the newly built or relocated civil transport airport should not exceed 4420m.

This paper analyzes the conversion relationship among air pressure, air pressure altitude and airport elevation in combination with the current situation of site selection in high plateau areas of Tibet, atmospheric pressure of high plateau airport and the analysis results of aircraft airworthiness. After that, an example of atmospheric pressure at a site in Tibet was analyzed to verify the feasibility of the site selection range breaking through the airport elevation of 4420m. Finally, the influence of atmospheric pressure data on the site selection of high plateau civil airport is summarized, and some suggestions are put forward.

2. AIRPORT Site selection status and airworthiness analysis of high altitude airports in Tibet

2.1 Site selection status of High Plateau Airport in Tibet

Tibet covers an area of 1.2 million square kilometers, accounting for about 1 / 8 of the total area of the country. By the end of 2021, there were 248 civil transport airports in the country, and the total number of airports in Tibet accounted for only 2% of the total number of airports in the country. The density of airports in Tibet is 0.4 per 100000 square kilometers, far lower than the national level of 2.0 per 100000 square kilometers. The density of airports in Tibet only accounts for 1 / 6 of the National Airport density. On the whole, there are relatively few airports in Tibet, and the uncoordinated situation that uneven distribution of airport in east and west exists long in Tibet. Airports mainly concentrated in the south. The main restricted factor is the high altitude, which exceeds the requirements of relevant specifications.

This paper classifies Tibet according to the altitude. As shown in Figure 1, the altitude below 4000m is gray, the altitude between 4000m and 4420m is yellow, the altitude between 4420m and 4470m is red, the altitude between 4470m and 4520m is blue, the altitude between 4520m and 4570m is light green, and the altitude above 4570m is dark green. It can be seen from Fig. 1 that 90% of the altitude of Tibet is above 4000m. Most of the remaining low altitude areas are located in the non-actual control area of Nyingchi and the lower reaches of the Yarlung Zangbo River. Suitable sites for site selection are in the river valley. Shigatse airport and Lhasa Airport have been arranged in the river valley. The flight conditions and construction conditions in the remaining areas are poor.

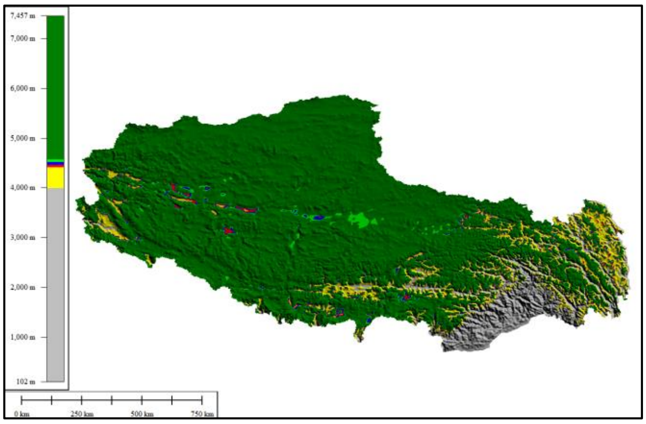

Fig. 1. Topographic classification map of Tibet

2.2 Atmospheric pressure of high plateau airport

As shown in Table 1, the QNH data of six high plateau airports in China are statistically analyzed in this paper. The QNH values of the six high plateau airports are significantly higher than the standard atmospheric pressure of 1013.25 HPA, which will be conducive to the improvement of aircraft engine performance and aerodynamic performance. Therefore, the airworthiness of aircraft can be studied through the analysis of atmospheric pressure data, and the feasibility of breaking through the site selection range of high plateau airports can be demonstrated from the perspective of aircraft airworthiness.

Table 1 Annual QNH statistical data

Airport ICAO Code	**Annual QNH statistical data (unit: HPA)**		
	Maximum value	***Minimum value***	***Average value***
ZULS	1028.2	1020.7	1024.7
ZUAL	1035.1	1024.0	1054
ZURK	1028.2	1021.2	1024.8
ZUDC	1035.3	1023.0	1029.5
ZUKD	1038.8	1020.1	1030.0
ZUBD	1037.0	1024.9	1031.2

2.3 The analysis of aircraft airworthiness

According to the operating aircraft types of domestic high plateau airports, the main operating aircraft types of high plateau airports with airport elevation over 4000m include B737-700w and A319. The operating envelope in the operation manuals of the three aircraft types is shown in Fig. 2 and Fig. 3. It can be seen from the operation envelope that the maximum takeoff and landing airport height of the three types of aircraft is 14500ft (4419m), which is also the source of the requirement in the relevant documents that the altitude of the newly built or relocated civil transport airport should not exceed 4420m. However, the altitude of the operation envelope in the operation manual of the aircraft is the pressure altitude, not the elevation above sea level of the airport.

For example the chapter " Altimeter Setting To Station Pressure" of B737 FPPM mention the following: "The determination of thrust setting and takeoff/landing performance generally requires station pressure altitude.[5]" "If station pressure or station pressure altitude are not available, enter the chart with altimeter setting (QNH) and read the pressure altitude adjustment. Apply this correction to the station elevation to obtain station pressure altitude.[5]" There are also relevant contents in the

Airbus operating manual. The contents in the operation manual of the above aircraft type further indicate that the operating envelope of highest airport altitude in the operating manual is the pressure altitude, not the elevation above sea level, and there is a certain conversion relationship between the pressure altitude and elevation above sea level. Therefore, we can find a breakthrough by analyzing the relationship between the pressure altitude and the elevation above sea level of the airport, appropriately breaking through the limitation that the elevation above sea level should not exceed 4420m, expanding the site selection range, and increasing the possibility of selecting sites with better ground and clearance conditions.

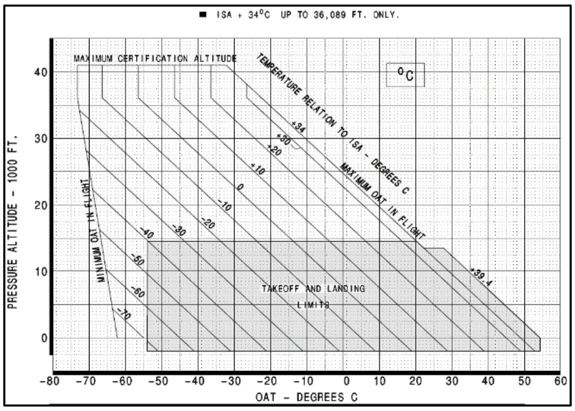

Fig. 2. Operation envelope of AFM Manual of Boeing B737-700 (relationship between pressure altitude and temperature)

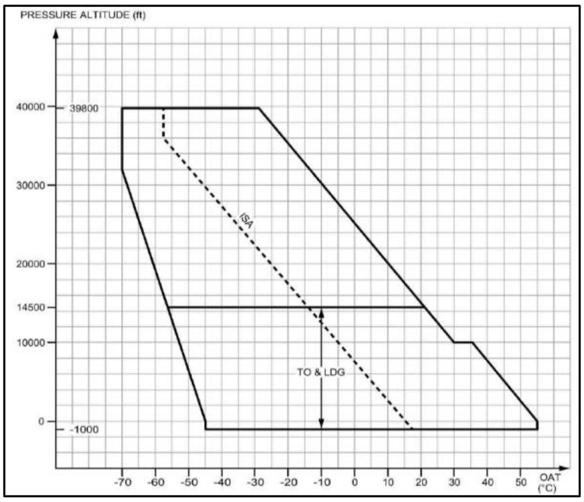

Fig. 3. Operation envelope of FCOM Manual of A319 (relationship between pressure altitude and temperature)

3. Analysis of the relationship between air pressure, air pressure altitude and airport elevation

3.1 Analysis of the relationship between QFE and QNH

QFE is the pressure at the airport reference point. If the temperature is at the standard temperature (ISA + 0 °C), when setting QFE, the altimeter indicates the altitude higher than the airport reference point. QNH is the mean sea level pressure. QNH is calculated by measuring the pressure at the reference point of the airport and then converting it to the average sea level according to the law of standard pressure. When the QNH setting value is used, if the temperature is at the standard temperature (ISA + 0 °C), the altimeter indicates the altitude higher than the average sea level. The statistical barometric data of the meteorological observation station set at the airport is QFE data. Based on this, it is necessary to study the standard pressure law and convert it into QNH value.

Under real atmospheric conditions, the conversion formula of QNH and QFE is as follows:

$$\text{QNH}=\text{QFE}\times \text{K}^{5.256} \quad (1)$$

$$K=288.15/\left(288.15-0.0065Z\right) \quad (2)$$

Where: QNH is the corrected sea pressure(unit: HPA); QFE is the field pressure(unit: HPA); Z is the airport elevation(unit: M).

The relationship between QFE and QNH is shown in Fig. 4.

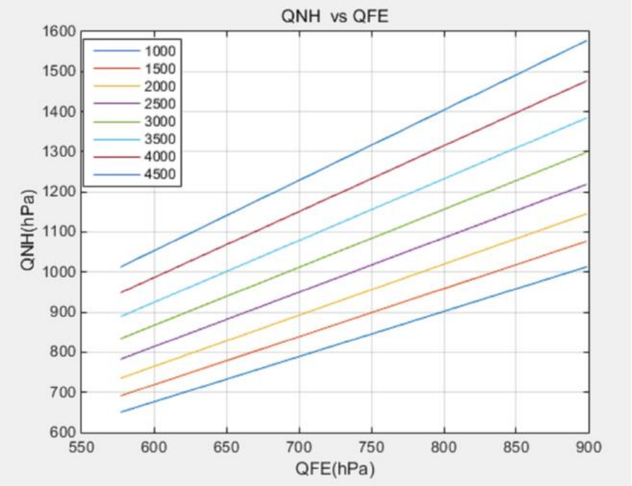

Fig. 4. Relationship between QNH and QFE

3.2 Analysis of the relationship between airport elevation and pressure altitude

The airport elevation is the measured altitude of the airport, and pressure altitude is the logical altitude obtained by the aircraft through atmospheric density calculation. The conversion relationship between the two can be derived by the following formula:

$$Hp=Ha+14544.2\times\left[1-\left(QNH/Po\right)^{0.1902631}\right] \quad (3)$$

Where: Hp is the pressure height(unit: FT); Ha is the airport elevation(unit: FT); QNH is the corrected sea pressure(unit: HPA); P0=1013.25 HPA.

Equation (1) and (2) are brought into (3) and sorted into the following formula:

$$QFE=\frac{\left[1-\left(Hp-3.2808Z\right)/145442.15\right]^{5.256}\times P_0}{\left[288.15/\left(288.15-0.0065\text{Z}\right)\right]^{5.256}} \quad (4)$$

In (4), QFE is the actual observation value and P_0 is a constant. Therefore, the conversion relationship between the pressure height and the airport elevation can be determined through the observation value of QFE. Assuming that the takeoff and landing envelope of the aircraft is 14500ft, the relationship between the maximum airport elevation of the optional site and QFE and QNH is shown in Fig. 5.

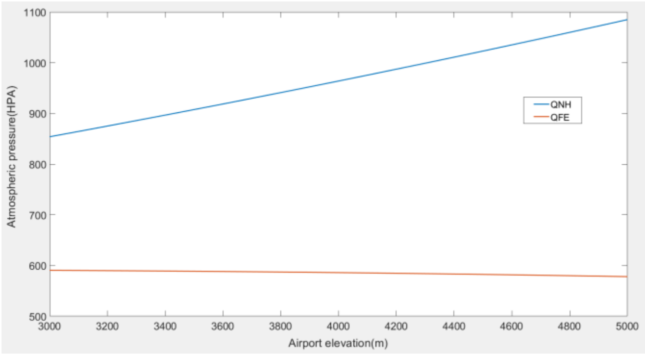

Fig. 5. Relationship between maximum airport elevation and QFE and QNH

4. Case analysis

4.1 Case description

A certain site of the proposed airport in Tibet has a site elevation above sea level of 4500m, and the proposed aircraft types are B737-700 plateau type and A319 type. The maximum takeoff and landing envelope of the two types aircraft is 14500ft. See Table 2 for the statistics of QFE data in 2020. Q: the site elevation above sea level is 4500m, and can it meet the requirements of the operation envelope in the manuals of the two types of aircraft planned for operation.

Table 2 Annual QFE statistics of the site in 2020

Month	**Annual QFE statistics of the site in 2020 (unit: HPA)**		
	Maximum value	***Minimum value***	***Average value***
1	601	599	600
2	602	600	601
3	603	601	602
4	605	603	604
5	605	603	604
6	606	604	605
7	606	604	605
8	607	605	606
9	608	606	607
10	607	605	606
11	606	603	605
12	604	601	603
Annual	608	599	604

4.2 Case analysis

The elevation above sea level of the site is 4500m. The measured QFE data of the site is shown in Table 2. The QNH value of the site can be calculated according to (1) and f (2), as shown in Table 3.

According to the site elevation above sea level of 4500m, the specified maximum pressure height for takeoff and landing operation of the two types of aircraft is 14500ft, and the minimum QFE and the minimum QNH under the site elevation calculated by (3) are 582.5hpa and 1023hpa respectively. In other words, if the statistical QFE value of the site is greater than 582.5 HPA and the derived QNH value is greater than 1023 HPA, the site meets the requirements of the operation envelope of the two planned aircraft types.

Table 3 QNH value derived from QFE statistics

Month	**Annual QNH statistics of the site in 2020 (unit: HPA)**		
	Maximum value	***Minimum value***	***Average value***
1	1054	1052	1053
2	1057	1053	1054
3	1058	1054	1057
4	1062	1058	1061
5	1062	1058	1061
6	1063	1061	1062
7	1063	1061	1062
8	1065	1062	1063
9	1067	1063	1065
10	1065	1062	1063
11	1063	1058	1062
12	1061	1054	1058
Annual	1067	1052	1061

Through analysis, the annual minimum QFE value of the site is 599 HPA, and the calculated annual minimum QNH value is 1052 HPA. Both values are greater than the minimum QFE value of 582.5hpa and the minimum QNH value of 1023hpa under the site elevation. Therefore, the airport elevation above sea level of 4500m at the site can meet the operation envelope requirements of the two planned aircraft types.

5. Conclusions and suggestions

The high plateau terrain in Tibet has obvious characteristics, which brings difficulties to the airport site selection. Through the study on site selection range of high plateau civil airport based on atmospheric pressure data analysis, the following conclusions are reached:

1) When the airport is operating at an elevation higher than 14500ft, as long as the air pressure of the airport is high enough, the aircraft has operational feasibility and meets the airworthiness certification requirements of its aircraft manufacturers, and there is no need to revise the relevant airworthiness certification restrictions in its AFM manual;

2) For airport site selection in Tibet, the height limit of 14500ft can also be gradually relaxed in combination with the atmospheric pressure conditions, thus greatly increasing the area and scope of airport site selection, and significantly improving the social and economic benefits.

The research shows that there are two main factors restricting the location of high altitude airports in Tibet: meteorological factors and aircraft airworthiness standards. If it is necessary to break the elevation limit of the existing site selection, it is recommended to do the following work:

1) Reasonable and effective observation and collection of complete and comprehensive meteorological data are of great significance to the site selection of the new airport. It is suggested to improve the meteorological observation equipment at the proposed site and collect more detailed and comprehensive meteorological data, especially key factors such as wind direction and air pressure, so as to comprehensively evaluate the operation safety and flight normality after the completion of the airport;

2) If conditions permit, communicate with aircraft manufacturers, continue to raise the upper limit of airworthiness certification envelope, and improve the range of site elevation from the perspective of aircraft itself.

References

[1] Zhang li'an, "Characteristics and design of plateau Airport," Airport Constructio, vol. 1, pp. 3-10, January 2008.

[2] Wang Kun, "Analysis of Selection Condition of High Plateau Airport," Journal of Civil Aviation, vol.6, pp.22-24, July 2022.

[3] Pei Zhao,Gu Xuejiao,Zhuang Yuan, "Research on the development of High Plateau Airports in China," Journal of Civil Aviation, vol.5, pp.19-23, September 2021.

[4] Li Ting, "Study on the influencing factors and methods of airport site selection on High Plateau," China Science And Technology Information, vol.13, pp.82-84, July 2016.

[5] Boeing Commercial Airplane Group, B737-700 Flight Plan and Performance Manual. Washington,U.S.A:Boeing Commercial Airplane Group,2010