THE ACOUSTIC RESEARCH ON ARCHITECTURAL SHAPE OF THE STAGE OF TRADITIONAL CHINESE THEATRES

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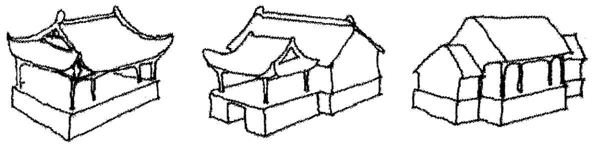
1 INTRODUCTION

1.1 The Basic Forms of Traditional Stage

The basic forms of the traditional Chinese stage can be broadly classified into three types[1] (Figure 1), namely single-block type, twofold vertical joint type and three-block paratactic type (单幢式、双幢前后勾连式和三幢左右并列式). The typical examples of these three types are respectively: the stage of Dong Yue temple in Linfen city, Dongyang village, Shanxi Province, (山西临汾市东羊村东岳庙戏台, Figure 2), Water and Mirror Stage of Jinci in Shanxi Province (山西太原市晋祠水镜台戏台, Figure 3) and the stage of San Guan temple in Baofu village, Zezhou county, Shanxi Province (山西泽州县保伏村三官庙戏台, Figure 4). Ancient Chinese designs in general were single-block type, although the number of their bays varied, and the support structure was combined with the roof. In addition to the single-block type, many traditional Chinese stages adopt a combination type of two or three monomers. This is also the very remarkable construction characteristic which the ancient stage possessed. There are two main reasons why the stage uses the combination method in construction monomers. First, during the Ming and Qing Dynasties, the dramatic performance place of the stage needed to expand. Second, the stage, as a performing space, was divided into two sharply distinguished functional parts which were the performance area and the music playing area, as well as the manifestation of the different requirement of spatial enclosure degree of forestage and backstage. Of course, in the different historical periods and different regions, different architectural forms of the stage either co-exist or some form remains in the dominant position.



(a) (b) (c)

Figure 1. Schematic diagram of the basic forms of traditional stage
(a. Single-block type, b. Twofold vertical joint type, c. Three-block paratactic type)
(Source: 《The Architecture of Traditional Chinese Theatre》, Linping Xue, 2009)

Figure 2

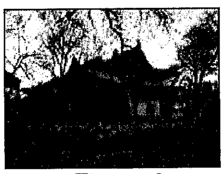


Figure 3

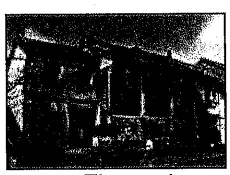


Figure 4

Figure 2. The stage of Dong Yue temple in Linfen city, Dongyang village, Shanxi Province
(The stage of single-block type)
(Source: Author, 2010)
Figure 3. The Water and Mirror Stage of Jinci in Shanxi Province
(The stage of twofold vertical joint type)
(Source: Author, 2010)
Figure 4. The stage of San Guan temple in Baofu village, Zezhou county, Shanxi Province
(The stage of three-block paratactic type)
(Source: 《The Architecture of Traditional Chinese Theatre》, Linping Xue, 2009)

1.2 The Side-View Forms of Traditional Stage

The ancient stage evolved from a gazebo (Figure5). According to the description of the performance scene of the courtyard of the Buddhist temple painted on the Dunhuang murals, the performance shows of the Sui and Tang dynasties on the gazebo, which can be divided into primary performance and secondary performance, had a four-sides-view form[2]. This view form has been extended forward to the Song and Jin Dynasties. But Xian Dian (献殿) and Wu Ting (舞亭) appeared during the Song and Jin dynasties, both of which were all-timber-framed constructions which can be used for opera performances. Among them, Xian Dian was mainly used for sacrificing, but also can be used for opera performance. Then, known as Wu Ting, which was mainly used for dancing, can also be used for displaying sacrifices. So, there was no strict distinction between them[3]. And their architectural shape was in the form of a pavilion which had four corner columns and was surrounded by the four open sides. This indicates that its view form was still four-sides-view form. It is worth noting that until the Ming and Qing dynasties, pavilion-style stages similar to the Xian Dian or Wu Ting were still constructed. The typical examples are: the stage of the Ming dynasty of Queen Mother pool of Tai Mountain in Tai'an city, Shandong province (明代山东泰安市泰山王母池戏台, Figure 6) and waterside stage of the Qing dynasty of He garden in Yangzhou city, Jiangsu province (清代江苏省扬州市何园水榭戏台, Figure 7).

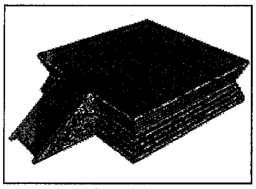


Figure 5

Figure 6

Figure 7

Figure 5. Schematic diagram of gazebo
(Source: Author, 2011)
Figure 6. The stage of the Ming dynasty of Queen Mother pool of Tai Mountain in Tai'an city, Shandong province
(Source: http://www.sdmuseum.com/museum/Prot?req=showNews&id=201)
Figure 7. Waterside stage of the Qing dynasty of He garden in Yangzhou city, Jiangsu province
(Source: http://hi.baidu.com/%BA%CE%C8%F3%BA%B2/blog/item/d0e45355913a0352574e007c.html)

With the development of opera performances and improvement of the environmental requirement of the dramatic appreciation, Xian Dian and Wu Ting began to further differentiate: Xian Dian remains the pattern opened on four surrounding sides. However, Wu Ting was begun to include a wall on the side which was the furthest one from the main hall, or to add another two walls on both lateral sides, consequently the two main side-view forms of traditional Chinese stage were formed, namely the stage of one-side-view form of photo-frame style and the stage of three-side-view form of extended style. The so-called photo-frame style is a stage built with walls on three sides, open on one side acting alone. For example, the stage of Zhen Wu temple in Hejin city, Shanxi procince (山西河津市真武庙戏台, Figure 8). The so-called extended style is a stage open on three sides, stretching out into the theater courtyard. For example, the stage of Qin's ancestral temple of Tian Yi Ge in Ningbo city, Zhejiang province (浙江宁波天一阁秦氏支祠戏台, Figure 9).

Apart from the three different side-view styles above, there is a rare two-side-view style, commonly known as Chuan Xin stage (穿心戏台). The so-called Chuan Xin stage, that is, a channel dividing the surface of the stage into two equal parts was set in the center of the pedestal. Usually, this stage served as a north-south channel. Some times, when acting opera plays, the slab would be put on, it can be served as the stage itself. For example, the stage of Chuan Xin Lou of Song Jia Zhuang in Wei county, Hebei province (河北蔚县宋家庄穿心楼戏台, Figure 10).

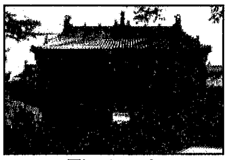
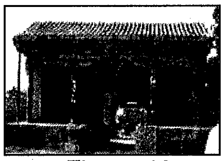
  

Figure 8 Figure 9 Figure 10

Figure 8. The stage of Zhen Wu temple in Hejin city, Shanxi procince
(Source: Author, 2010)

Figure 9. The stage of Qin's ancestral temple of Tian Yi Ge in Ningbo city, Zhejiang province
(Source: Author, 2010)

Figure 10. The stage of Chuan Xin Lou of Song Jia Zhuang in Wei county, Hebei province (Source: http://blog.163.com/mmzzyy3620@126/blog/static/76626290200971794717504/)

1.3 The Width of Traditional Stage

Consistent with the side-view transformed from four-side-view style to three-side-view or one-side-view style, the surface of the stage also developed from square to rectangular shape, so the width of most stages became from one-bay wide to three-bays wide. The shape of the surface of most stages of the Yuan dynasty was square, but in fact as for the performance area itself, it was rectangular, because the backstage would occupy about one third of the back area of the stage. For example: the stage of Niu Wang temple of Wei village in Linfen city, Shanxi province (山西临汾市魏村牛王庙戏台, Figure 11). During the Ming dynasty, the width of lots of stages began to appear in the form of three bays wide, such as: the stage of Guan Di temple of Fan village in Hejin county, Shanxi province (山西河津县樊村关帝庙戏台, Figure 12). The reason why the stage with 3-bay wide was so popular in the Ming Dynasty was mainly thanks to the progress of opera performances and reduction of the timber resources. Therefore, the advantage of the three-bay wide stage is: not only could it provide a broader stage to the performers than before, but also it could ensure the stage was no longer limited by the wooden structure on the architectural size of the span of the width. So their appearance could be more diverse, not just a simple pavilion style. Most of the width of the stage of Qing dynasty inherited the features of the stage of the Ming Dynasty. But there are also individual examples, such as the stage of Garden of Virtuous Harmony in the Summer Palace (颐和园德和园大戏楼), one of the great palace theaters in Beijing, was five bays and nine bays wide (Figure13).

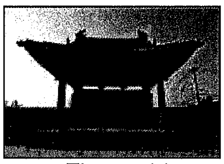
  

Figure 11 Figure 12 Figure 13

Figure 11. The stage of Niu Wang temple of Wei village in Linfen city, Shanxi province
(Source: Author, 2010)

Figure 12. The stage of Guan Di temple of Fan village in Hejin county, Shanxi province
(Source: Author, 2010)

Figure 13. The stage of Garden of Virtuous Harmony in the Summer Palace
(Source: Author, 2010)

1.4 The Depth of Traditional Stage

Relative to the width of the stage, most stages also had a certain increase in the dimension of the depth, but were less significant. The reason for this is because the system of beam and ridge itself determine the increase in depth of the stage can not be too much. Except the dragon and tiger temple of Yongle palace in Miao city (苗城永乐宫龙虎殿), all the stages of Song Jin and Yuan dynasties, without exception, adopted a form of depth with a width of two bays wide. Till the Ming and Qing dynasties, many stages still maintained the pattern of 2:1 in the ratio of the depth between forestage and backstage. But in addition to the part of the stage carrying forward the "pavilion style" of the Yuan dynasty all the same, most of the stage had a clear division between the forestage and backstage. The logo is not only a wooden wall or tent apart from the forestage to backstage, but also had the columns as a separator which was located within the interior of the stage and outside the flat gable walls. At the same time, there were two doors opened on both sides of the wooden wall or tent, usually two characters "Chu Jiang"(出将) and "Ru Xiang"(入相) as the sign of exit and entrance were written on the top of these two doors separately. For example, the stage of Cheng Tang temple in Shangfu village, Yangcheng county, Shanxi province (山西阳城县上伏村成汤庙戏台, Figure 14-15). There was a phenomenon that the depth of the backstage was comparable to that of the forestage in many twofold vertical joint stages of the Ming and Qing dynasties, or even the former was longer than the latter. Meanwhile, the depth of the vestibule stage (山门戏台) also had increased to some extent. And it is noteworthy that one of the most famous palace theater, the great theatre of Garden of Virtuous Harmony in Summer Palace, has 3 bays long in the forestage which is 14.7 meters, and 5 bays in the backstage which is 17.4 meters, the whole depth of the stage even reaches 32.1 meters long.

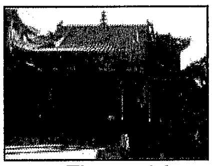


Figure 14

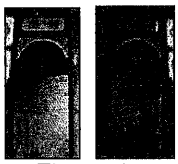


Figure 15

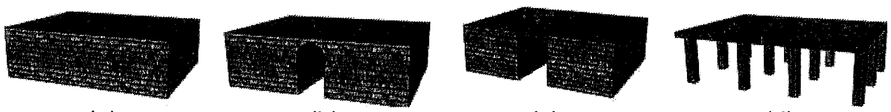
Figure 14. The stage of Cheng Tang temple in Shangfu village, Yangcheng county, Shanxi province
(Source: Author, 2010)
Figure 15. The exit and entrance of the stage of Cheng Tang temple in Shangfu village, Yangcheng county, Shanxi province
(Source: Author, 2010)

1.5 The Frame of Proscenium Arch of Traditional Stage

Because of the special architectural nature of traditional Chinese theater, three-side-view stages existed for a long time and played an important role in history, but its frame of the proscenium arch may have played a much less important role in than in a Western theater. In a Western Theater, its function is a one-side-view form of a photo-frame style (The frame of the proscenium arch of the Western theater directly led to the development of stage scenery). Because the large number of stages of the Ming and Qing dynasties and a general lack of the specific sizes from all the public publishing data, it is impossible to get accurate data about the size of the frame of proscenium arch at present. According to statistics, the aspect ratio of the frame of proscenium arch of the stage of the Yuan dynasty has a large variation in range. The smallest value of variation is 1:2.80, while the largest value reaches 1:1.63, the corresponding height to width aspect ratio of the stage was slightly smaller than that of the frame of proscenium arch. Speculating from the mainstream situation of the three-bay-wide stage, the height to width aspect ratio of the whole frame of the proscenium arch of the Ming and Qing dynasties should be less than that of the Yuan dynasty. To do a simple projection from the regulation of "wooden construction method of large timber without corbel arch" (无斗拱大木大式做法) in the book 《Construction Examples of the Qing Dynasty》 [4] (清式营造则例), the ratio value[5] of the width of the stage to the height of the column (including the height of the column base) is 1:3.21. It could not conclude that the values of the height of the column to width of the stage aspect ratio of the three-bay-wide stage of the Ming and Qing dynasties were generally greater than that of the ancient buildings, but comparing with that ratio values of single-bay-wide stage of the Yuan dynasty, their decline trend was obvious. Because of this phenomenon, the "photo frame" which shows the dramatic performances to the audience had became more compressed, and the area of the frame of proscenium arch had a certain degree increase without changing the height of the proscenium arch. This is beneficial to the visual effect. Wide-screen film which was born in the 1950's used this method to enhance the visual impact[6].

1.6 The Pedestal of Traditional Stage

The pedestal is a very important Constituent Element of traditional Chinese architectures. It possesses the multifunction of water tightness, stability, adjusting architectural composition, expanding architectural volume and labeling grade[7]. To contrast the pedestal of traditional Chinese architecture to the roof and the building itself, the pedestal often appears to be a little bit stylized, immobile and simplistic. But for the stage, the pedestal from is more elaborate. The pedestal of the stage is not only used as a base, but also solves the people's access problem. The form of the pedestal of the stage can be divided into two categories, namely a solid pedestal and a hollow pedestal (Figure 16). The typical example of solid pedestal is the stage of Wan Shou palace in Wang Xian Zhuang village, Ji county, Shanxi province (山西祁县王贤庄村万寿宫戏台, Figure 17). The hollow pedestal can also be divided into arch construction type, board covering type and column supporting type (Figure 16). The typical examples are the stage of Black Dragon temple in Jikou town, Lin county, Shanxi province (山西临县碛口镇黑龙庙戏台, Figure 18), the stage of Chuan Xin Lou in Song Jia Zhuang village, Wei county, Hebei province (河北蔚县宋家庄穿心楼戏台, Figure 10) and the stage of Qi An Guild House in Huguang Guild Hall, Chongqing city (重庆湖广会馆齐安公所戏台, Figure 19).



(a) (b) (c) (d)

Figure 16. Schematic diagram of common forms of the pedestal of traditional stage (a. Pedestal of solid type, b. Pedestal of arch construction type, c. Pedestal of board covering type, d. Pedestal of column supporting type)
(Source: Author, 2011)

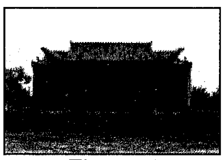


Figure 17

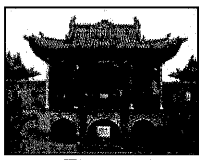


Figure 18

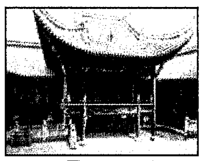


Figure 19

Figure 17. The stage of Wan Shou palace in Wang Xian Zhuang village, Ji county, Shanxi province
(Source: Author, 2010)
Figure 18. The stage of Black Dragon temple in Jikou town, Lin county, Shanxi province
(Source: http://hi.baidu.com/yasos/blog/item/53944c24f1c95029d5074232.html)
Figure 19. The stage of Qi An Guild House in Huguang Guild Hall, Chongqing city
(Source: Author, 2009)

2 RESEARCH METHODOLOGY

2.1 Acoustic Simulation Tool

Detailed simulations were made by using acoustic software CATT-Acoustic (Version 8.0d). CATT is based on the combination of image source model for early part echogram qualitative detail and ray-tracing[8].

2.2 Research Thread

It is well-known that the basic shape elements of an ancient stage are width, depth, height of the frame of proscenium arch and height of the pedestal. Among them, the width of the ancient stage was in the range of 3-18 meters, mostly about 9 meters. The depth of the ancient stage was in the range of 3-13 meters, mostly around 5 meters. The height of the frame of proscenium arch was in the range of 2.5-4.5 meters, mostly about 4 meters. The height of the pedestal of the ancient stage was in the range of 0-4 meters, mostly around 1.5 meters. Therefore, we can fix as constant three of four of these basic shape elements of the abstract ancient stage in their general values, and make one of the elements vary gradually according to a unit scale. Then we can analyze and discuss the impact of such an element on the sound field of traditional Chinese theatres. This article focused on the simulation and analysis of three main types of traditional stage. They are the stage of one-side-view form of photo-frame style (镜框式一面观戏台), the stage of two-side-view form of forward-and-backward style (前后式两面观戏台) and the stage of three-side-view form of extended style (伸出式三面观戏台). For the same style of the stage, this paper adopted a vertical analyzing research method on a dimensional gradient. While, for the different style of the stage, this paper adopted a horizontal comparing research method on architectural characteristic.

2.3 Simulation Settings

1. Omni-directional sound source is located in the middle of the stage, it is 1.6 meters in height from the surface of the stage, and it is 2.5 metes away from the proscenium. No matter how the shape of the abstract stage changes, the sound source always maintains this position the same.
2. The dimensions of the background space are Length × Width × Height = 50 × 50× 10 meters, and set the Omni-directional sound source at the center of the plane of this background space.
3. The receivers in the auditorium area are all 1.6 meters in height from the ground, the total number of these receivers is 100, and the distance between each receiver is 2 meters, the whole of the receivers arranged in a square grid-like layout whose length and width are all 10 meters.
4. CATT settings are showed below:

Src: 70 73 76 79 82 85 : 95 95 (Manual Book)
Wall = < 2 3 3 4 5 7 > L < 10 10 10 10 10 10 > (BB93)
Stage = < 2 3 3 4 5 7 > L < 10 10 10 10 10 10 > (BB93)
Earth = < 2 3 3 3 4 7 > L < 20 20 20 20 20 20 > (BB93)
Roof = < 15 11 10 7 6 7 > L < 70 70 70 70 70 70 > (BB93)
Pedestal = < 2 3 3 4 5 7 > L < 10 10 10 10 10 10 > (BB93)
Void = < 99.9999 99.9999 99.9999 99.9999 99.9999 99.9999 > L < 0 0 0 0 0 0 >

2.4 Additional Remark

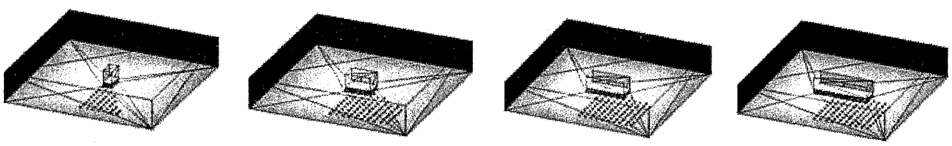
1. This paper adopted an assumptive research method to discuss the relationship between the shape and type of ancient stage and sound field of the theatre. One of the basic shape elements of the stage was assumed to change gradually in this assumptive research method. Therefore, all the models of the stage run in the CATT were not real ancient stages, but only a simple idealized model of the stage to facilitate the research and study, the paper called them an abstract ancient stage.
2. The roof structure of the ancient stage was quite complex. In addition to the existence of the column and tie construction and post and lintel construction, there are a large number of load-bearing components, such as brackets, and decorative elements, such as caisson ceiling. So, it was more reasonable that the diffusion coefficient of the internal surface of the roof was set to 70.
3. The shape of the roof of the ancient Chinese stage was complex and diverse, but it normally adopted the shape of pitched roof, such as the most commonly used shape was gable and hip roof with single eaves. However, in order to get the convenience of the simulation, this paper set the shape of roof of all types of abstract stage to be flat form instead of pitched form. Because of the complex structure of the roof and large diffusion coefficient of the internal surface of the roof, it was only reasonable that the roof of all types of abstract stage here can be set to a flat form.
4. Because these open-air theatres are not enclosed spaces, the desired value of EDT, T15 and T30 can not be obtained by the CATT simulation directly. In order to get these values of reverberation time, it is necessary to set up a large "background space"——Length × Width × Height = 50 × 50× 10 meters, and placed the stage in the central of this space. All the open sides of this "background space", named "Void" above, were given an absorption coefficient of 99.9999%.
5. In order to facilitate the research on the relationship between architectural form of ancient stage and the sound quality of the sound field and obtaining the clear and intuitive sound field distribution color photos, all the diffusion coefficients of the surfaces of the background space here were set to 0, i.e. they were considered to be absolutely smooth surfaces.

6. Because CATT software was mainly designed by the principle of geometric acoustics, it has a certain limitation on the simulation of sound diffraction phenomenon produced by the sound volatility. Therefore, when using software CATT to analyze acoustic quality parameters of traditional theatre, it should mainly consider the parameters within the non-diffraction region of the theatre. Meanwhile, in the actual traditional theater, the diffraction region of the theatre itself was a visual blind spot to the audience, that is, the audience within this region can not see anything about the dramatic performances when the opera actors are performing on the stage. So, the acoustic quality parameters within this diffraction region would naturally lose the analytical value and necessity. During the CATT simulation, this paper only considered and analyzed the various acoustic quality parameters of the receivers located in the non-diffraction region.
7. As been well known, basic skills of dramatic singing emphasized on the breath of the Dantian elixir field (Chinese: 丹田之气) transmitting the voice further and clearer. Simultaneously, skills of dramatic dialogue also differed from normal speech, particularly concerning articulation. Therefore, most Chinese dramatic singing tunes were very highly pitched, the main frequencies concentrated on the high frequency spectrum. Here, selecting 1000Hz as the main frequency operated in the CATT simulation should be more appropriate for traditional Chinese theatres.

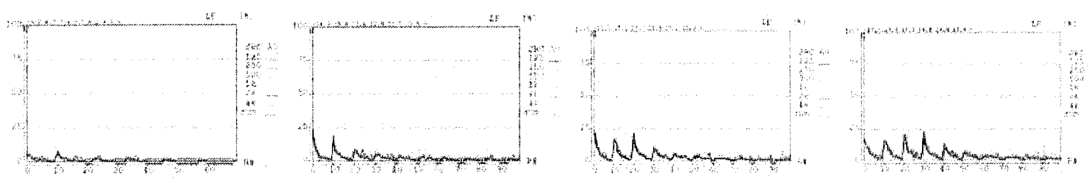
3 RESULTS AND DISCUSSIONS

3.1 The Simulation and Analytical Results of the Stage of One-Side-View Form of Photo-Frame Style

Assumption one: keeping the abstract one-side-view stage of photo-frame style at a constant depth of 5 meters, the frame of proscenium arch at a constant height of 4 meters and the pedestal at a constant height of 1.5 meters, when the width of the abstract stage increased from 3 meters to 18 meters in a single increment of 5 meters (Figure 20), the following conclusions can be drawn by analyzing the charts and pictures below:



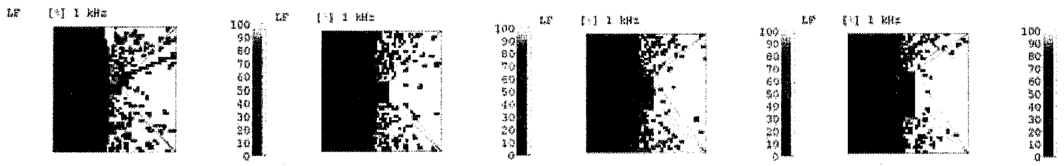
(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide
Figure 20. The gradual change in the width of the abstract stage



(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide
Figure 21. Curve charts of LF

1. It can be seen from Figure 21 that the values of LF in the audience region of the theatre are very low, the highest value not exceeding 25, each overall average is below 10, even in Figure 20 (a) it is close to 0. This is because nothing around the abstract stage can provide lateral sound reflections. Therefore, the lateral reflections are mainly provided by the two small gable walls of the abstract stage. In addition, the trend of the values of LF along the longitudinal direction of the audience area is that the further away from the abstract stage the receiver is, the smaller the corresponding value of LF becomes. This is because the further away from the abstract stage the receiver is, means that the receiver is further from these two gable walls, so naturally the receiver receives less corresponding energy of lateral sound reflections .
2. Figure 21 also shows that when the width of the abstract stage gradually increases, the variation range of the value of LF essentially unchanged, it still remains in the range of 0 to 25. That means

the amount of the total energy of the lateral reflections of the audience area of the theatre is essentially unchanged. This is because in the same sound source condition, the amount of energy of the lateral reflections of the theatre is in relationship with the size of the area of the boundary which reflects the lateral reflections. The larger area the boundary has, the more energy of the lateral reflections it reflects. Here, the main energy of the lateral reflections is provided by these two gable walls, since only the width of the stage increases, the depth of the stage and height of the proscenium arch remain the same, the size of the area of these two gable walls will remain the same. Therefore, the total amount of energy of the lateral reflections of the theatre will remain the same.

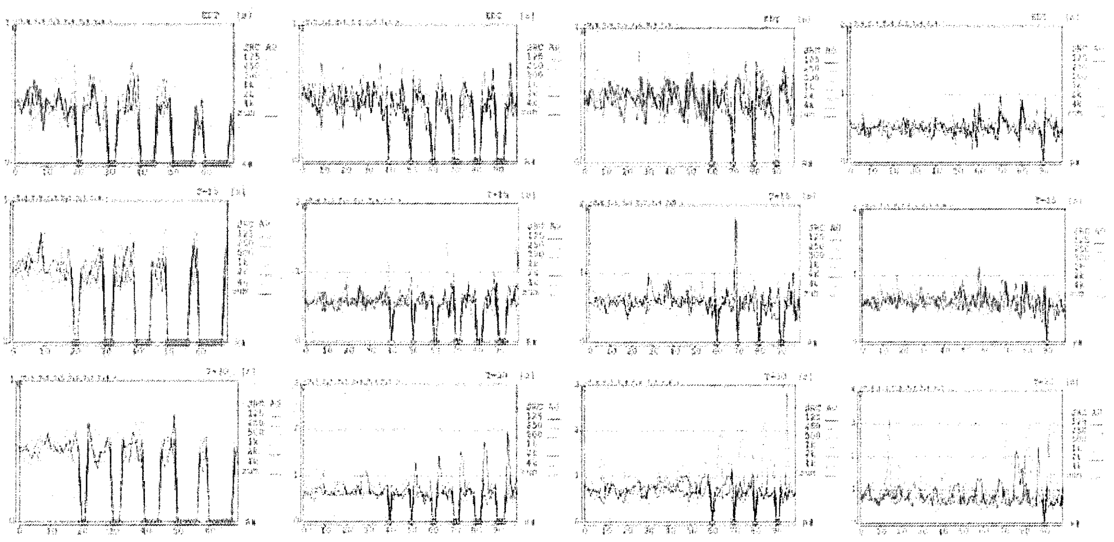


(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 22. Color pictures of LF

It is also worth noting that the variation range of the value of LF in Figure 21 (a) is in the range of 0 to 6 which is significantly less than the range of 0 to 25 in other three tables. However, this does not mean that the energy of the lateral reflections provided by the stage in the width of 3 meters is less than that provided by the stages in other three widths. But because the width of this stage is very small, of only 3 meters wide, by comparing with those color pictures in Figure 22, it can be clearly seen that a large amount of its energy of lateral reflections at this time is mainly concentrated on the stage, while the energy of lateral reflections of the stages of the other three widths has been mostly spread to the audience area. Thus, the energy of lateral reflections in the audience area of the stage in the width of 3 meters is significantly less than that of the stage in other three widths.

3. It also can be seen from Figure 22 that when the width of the stage gradually increases, the coverage of the lateral reflections in the audience area is also enlarged. Meanwhile, there is an inconspicuous ">" symbol-like flare in the color pictures of energy distribution of lateral reflections in the audience area. Both phenomena can be explained by the principles of geometrical acoustics.

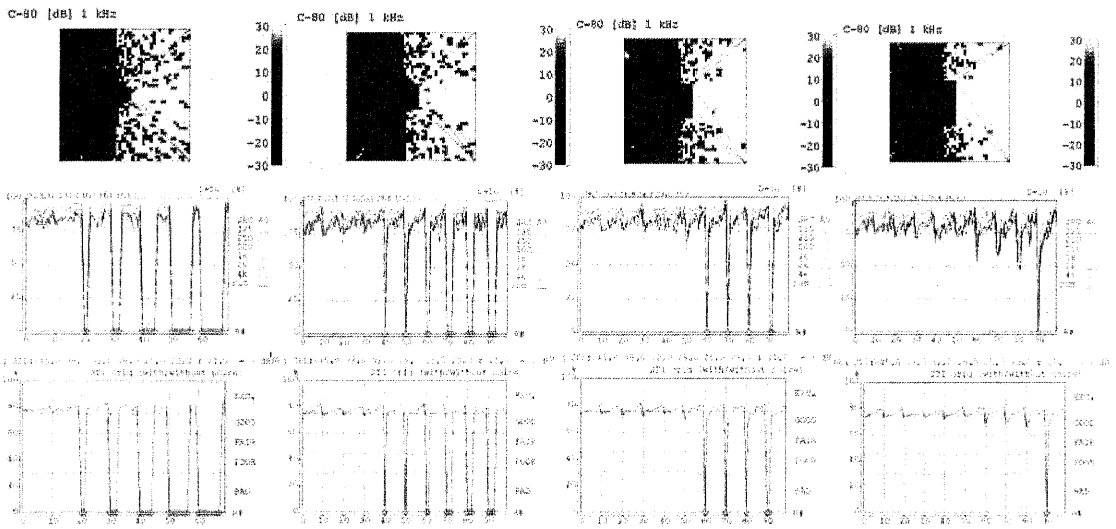


(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 23. Curve charts of reverberation time

4. As the width of the stage increases, the volume of the stage correspondingly becomes greater. In accordance with the theory of Sabine formula (RT60 = 0.161V\Sa. Where RT60 is the reverberation time, V is the volume of the room in cubic feet, and Sa is the total absorption, S is the surface area,

can be used as the perfect tool to calculate the total absorption) the value of the reverberation time should be also increased correspondingly. It can be seen from Figure 23 that the values of EDT, T15 and T30 have really increased with gradually increasing width of the stage. But their increments are very small, the average increment is only about 0.15 seconds. This is because, in the same sound source condition, the length of the reverberation time of the theatre mainly relates to the amount of energy of the reverberant sound. Because the depth and height of the stage does not change, when the increasing width of the stage leads to the increase of the volume of the stage, the area of the open side of the stage which is also the area of the proscenium arch is also increased accordingly. It directly leads to the increase of the degree of energy loss of the reverberant sound. Therefore, although the volume of the stage increases gradually, the actual increment of reverberant sound energy is not large. It leads that the increments of the value of EDT, T15 and T30 of the sound field of the theatre are also not large.



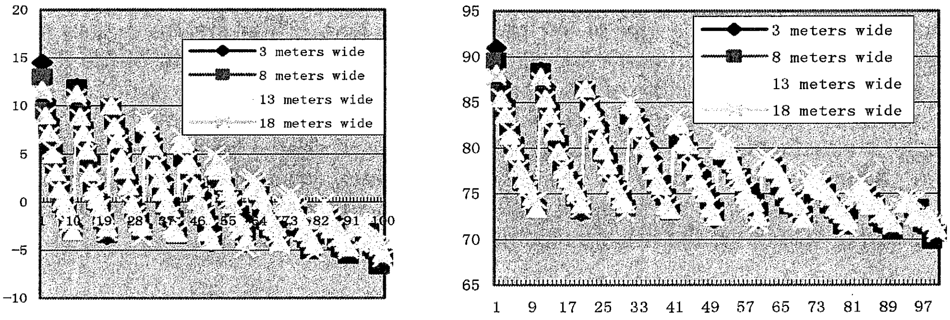
(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 24. Color pictures and curve charts of C80, D50 and STI

5. It can be seen from Figure24 that the values of D50, C80 and STI decrease when the width of the stage gradually increases. But the decrease extent is very small, all the values of D50, C80 and STI are almost unchanged. This is because all these tone quality parameters of the theatre mainly relate to the amount of the reverberant sound energy, especially relating to that of 50ms or 80ms later. Namely, in the same sound source condition of a theatre, the more the reverberant sound energy the theatre has, the lower the values of D50, C80 and STI. However, according to the reason mentioned above, although the volume of the stage increases gradually, the actual increment of reverberant sound energy is not large. So, it leads that the decreases of the value of EDT, T15 and T30 of the sound field of the theatre are also not large.

6. It can be seen from Figure 25 that the values of G and SPL decrease when the width of the stage gradually increases. But the decrease rate of the value is very small, all the values of G and SPL are almost unchanged. This is because the total sound energy of the audience area is mainly composed of the direct sound energy provided by the sound source and the reflected sound energy provided by the stage. Therefore, the values of SPL and G of the receiver point not only relate to the distance between the receiver point and sound source, but also relate to the distance between the receiver point and all the surfaces of the stage. In the process of changing the width of the stage, the relative position of the sound source in relation to the receiver points maintains the same, so the amount of the direct sound energy gained by the receiver points is unchanged. In addition, because the depth and height of the stage does not change, the distance between the receiver points and the back wall, roof and surface of the stage is also unchanged. Therefore, the amount of the reflected sound energy gained by the receiver points and provided by these surfaces of the stage is almost unchanged. The increase of the width of the stage leads to the increase of the distance

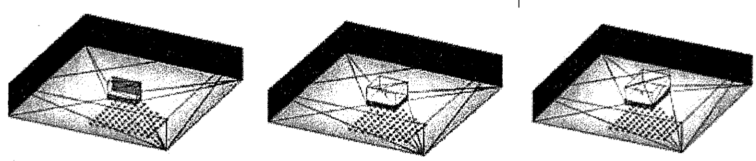
between the receiver points and two gable walls of the stage. Therefore, the lateral reflected sound energy gained by the receiver points and provided by these two gable walls correspondingly reduces. Consequently, the value of G and SPL of the audience area of the theatre decreases.



(a) (b)

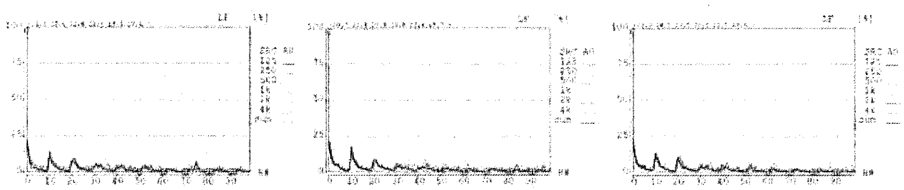
Figure 25. Curve charts of G (a. Sum) and SPL (b. Sum)

Assumption two: keeping the abstract one-side-view stage of photo-frame style at a constant width of 9 meters, the frame of proscenium arch at a constant height of 4 meters and the pedestal at a constant height of 1.5 meters, when the depth of the abstract stage increased from 3 meters to 13 meters in a single increment of 5 meters (Figure 26), the following conclusions can be drawn by analyzing the charts and pictures below:



(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 26. The gradual change in the depth of the abstract stage

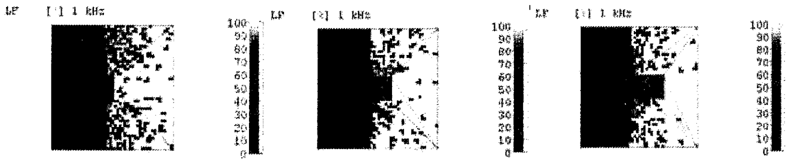


(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 27. Curve charts of LF

1. It can be seen from Figure 27 that, as the same phenomena described in assumption one, the values of LF in the audience region of the theatre are very low, the highest value not exceeding 25, each overall average is below 10. In addition, the trend of the values of LF along the longitudinal direction of the audience area is that the further away from the abstract stage the receiver point is, the smaller the corresponding value of LF. The reasons have been mentioned above.

2. The Figure 27 also shows that when the depth of the abstract stage gradually increases, as the same phenomena described in assumption one, the variation range of the value of LF essentially unchanged, it still remains in the range of 0 to 25. That means the amount of the total energy of the lateral reflections of the audience area of the theatre is essentially unchanged. Here, the main energy of the lateral reflections is provided by these two gable walls, since the width of the stage and height of the proscenium arch remain the same, the increase of the depth of the stage will lead to the increase of the area of two gable walls. According to the principle mentioned above, the lateral reflected sound energy of the audience area of the theatre will also be increased correspondingly.

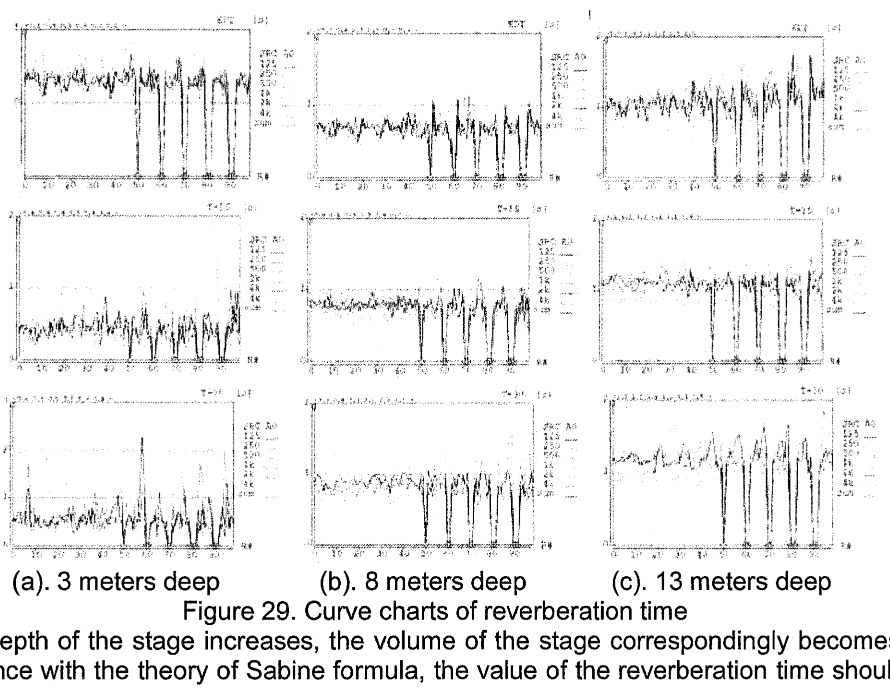


(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 28. Color pictures of LF

However, why does the amount of lateral reflected sound energy of this region still stay the same? In fact, there is nothing wrong with the interpretation of the principle mentioned above. It can be obviously seen from Figure 28 that with the increase of the depth of the stage and area of two gable walls, the lateral reflected sound energy actually also increases, only the increasing lateral reflected sound energy mainly concentrates at the back of the sound source, that is the increasing region of the stage. This is because the distance between the sound source and the apron stage remains unchanged at 2.5m, it follows that the effective area of two gable walls located on both sides of the front of the sound source does not increase, while the effective area of two gable walls located on both sides of the back of the sound source increases with the increase of the depth of the stage. Among these two effective areas, the front provides the lateral reflected sound energy to the audience area, the rear provides it to the increasing part of the stage. Therefore, when the distance between the sound source and the apron stage is fixed, the amount of energy of the lateral reflections in the audience area of the theatre is almost constant with the increase of the depth of the stage. The exception is that the amount of the energy of lateral reflections in the increasing part of the stage becomes larger along with that.

3. It can be seen from Figure 28 that when the depth of the stage gradually increases, the coverage of the lateral reflections in the audience area almost stays the same. Meanwhile, there is an inconspicuous “>” symbol-like flare in the color pictures of energy distribution of lateral reflections in the audience area. Both phenomena can be easily explained by the principles of geometrical acoustics.

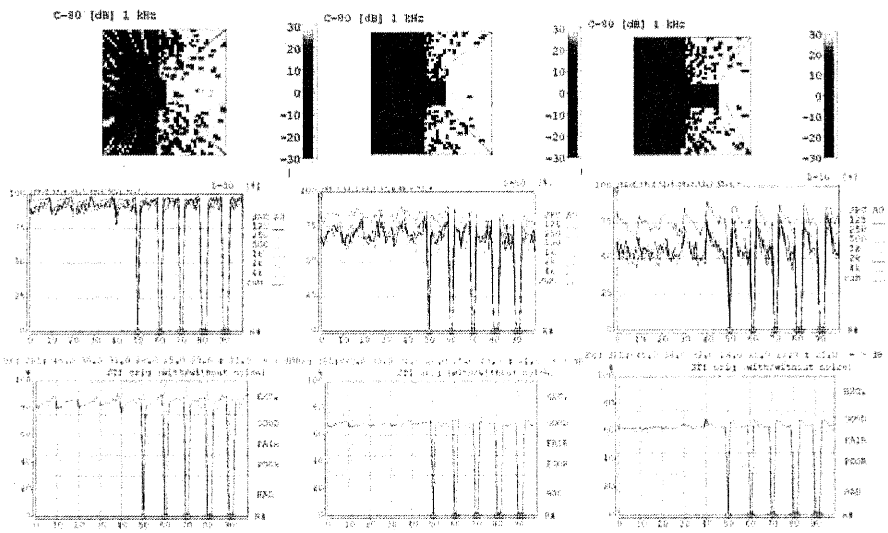


(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 29. Curve charts of reverberation time

4. As the depth of the stage increases, the volume of the stage correspondingly becomes greater. In accordance with the theory of Sabine formula, the value of the reverberation time should be also increased correspondingly. It can be seen from Figure29 that the values of EDT, T15 and T30 have really increased with gradually increasing depth of the stage. However, it is different from the phenomenon in assumption one that the rates of increase of the value of EDT, T15 and T30 here are quite apparent, this also means a large increment, some increments even close to 1 second. It

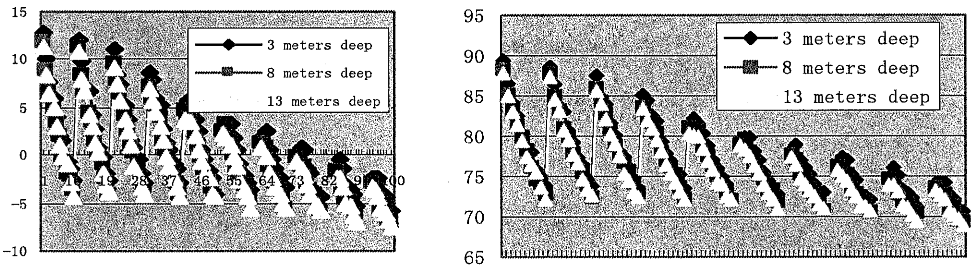
has been mentioned above that in the same sound source condition the length of the reverberation time of the theatre mainly relates to the amount of the energy of the reverberant sound. Comparing with the pre-condition of assumption one, the width and height of the stage does not change, when the increasing depth of the stage leads to the increase of the volume of the stage, the area of the open side of the stage which is also the area of the proscenium arch does not change, so the degree of energy loss of the reverberant sound of the stage does not change either. Therefore, along with the gradual increasing volume of the stage, the actual increment of reverberant sound energy is clear enough. It leads that the rates of increase of the value of EDT, T15 and T30 of the sound field of the theatre are more evident than that in assumption one.



(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 30. Color pictures and curve charts of C80, D50 and STI

5. It can be seen from Figure30 that the values of D50, C80 and STI decrease when the depth of the stage gradually increases. However, it is different from the phenomenon in assumption one that the rates of decrease of the value of D50, C80 and STI here are quite apparent, this also means a large decrement. As mentioned above, all these tone quality parameters of the theatre mainly relates to the amount of the reverberant sound energy, especially relating to that of 50ms or 80ms later. Because along with the gradual increasing volume of the stage, the actual increment of reverberant sound energy here is larger than that in assumption one, the rates of decrease of the value of D50, C80 and STI here are accordingly more obvious than that in assumption one.



(a) (b)

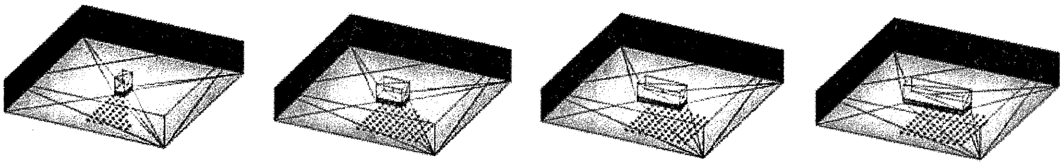
Figure 31. Curve charts of G (a. Sum) and SPL (b. Sum)

6. It can be seen from Figure 31 that the values of G and SPL decrease when the depth of the stage gradually increases. It is the same as the phenomenon in assumption one that the decrease rate of the value is also very small, all the values of G and SPL are almost unchanged. This is because in the process of changing the depth of the stage, the relative position of the sound source in relation to the receiver points maintains the same, so the amount of the direct sound energy gained by the receiver points is unchanged. In addition, because the width and height of the stage does not change, the distance between the receiver points and two gable walls, roof and surface of

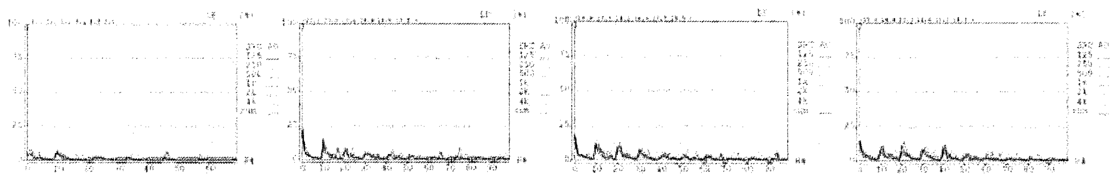
the stage is also unchanged. Therefore, the amount of the reflected sound energy gained by the receiver points and provided by these surfaces of the stage is almost unchanged. The increase of the depth of the stage leads to the increase of the distance between the receiver points and the back wall of the stage. Therefore, the reflected sound energy gained by the receiver points and provided by the back wall of the stage correspondingly reduces. Consequently, the value of G and SPL of the audience area of the theatre decreases.

3.2 The Simulation and Analytical Results of the Stage of Two-Side-View Form of Forward-and-Backward Style

Assumption three: keeping the abstract two-side-view stage of forward-and-backward style at a constant depth of 5 meters, the frame of proscenium arch at a constant height of 4 meters and the pedestal at a constant height of 1.5 meters, when the width of the abstract stage increased from 3 meters to 18 meters in a single increment of 5 meters (Figure 32), the following conclusions can be drawn by analyzing the charts and pictures below:



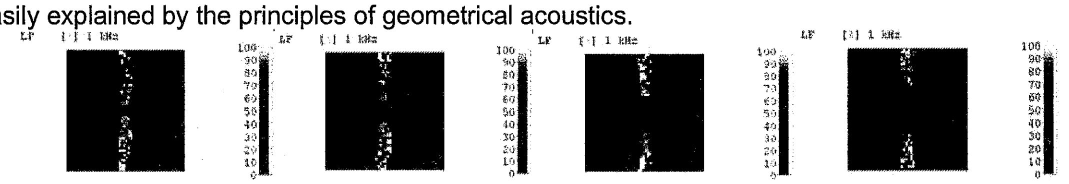
(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide
Figure 32. The gradual change in the width of the abstract stage



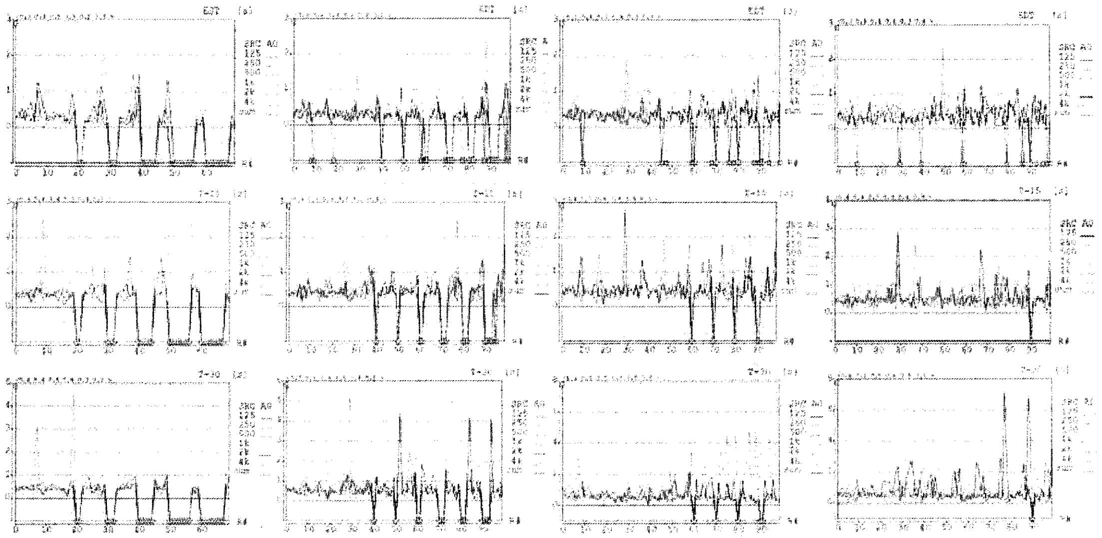
(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide
Figure 33. Curve charts of LF

1. It can be seen from Figure 33 that, just like the phenomena described in assumption one, the values of LF in the audience region of the theatre are very low, the highest value not exceeding 25, each overall average is below 10, even in Figure 33 (a) it closes to 0. In addition, the trend of the values of LF along the longitudinal direction of the audience area is that the further away from the abstract stage the receiver is, the smaller the corresponding value of LF. Furthermore, the Figure 33 also shows that when the width of the abstract stage gradually increases, the variation of the value of LF is essentially unchanged, it still remains in the range of 0 to 25. That means the total amount of energy of the lateral reflections of the audience area of the theatre is essentially unchanged. All the reasons of these phenomena have already been mentioned in assumption one.

2. It can be seen from Figure 34 that, just like the phenomena described in assumption one, when the width of the stage gradually increases, the coverage of the lateral reflections in the audience area is also enlarged. Meanwhile, there is an inconspicuous ">" symbol-like flare in the color pictures of energy distribution of lateral reflections in the audience area. Both phenomena can be easily explained by the principles of geometrical acoustics.



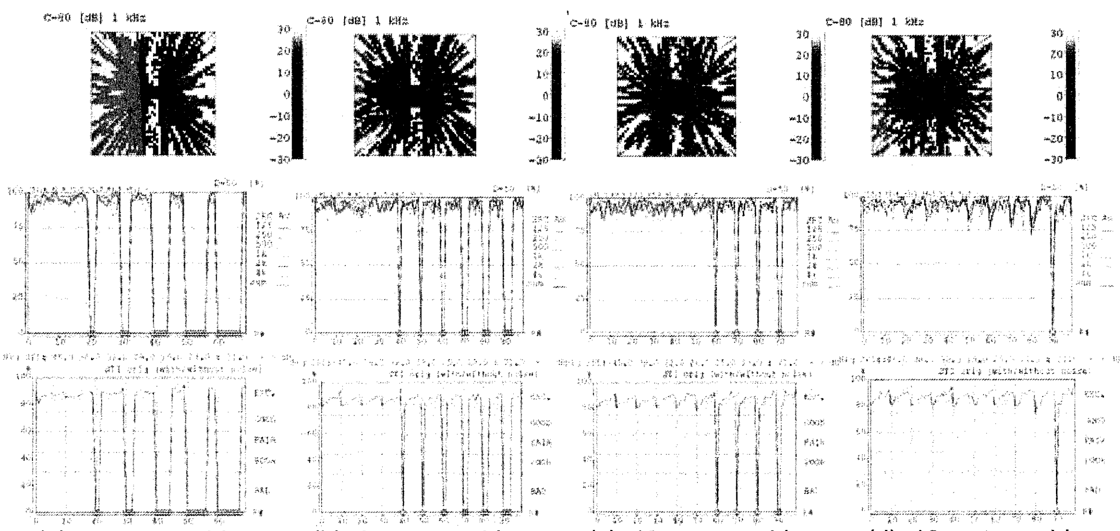
(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide
Figure 34. Color pictures of LF



(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 35. Curve charts of reverberation time

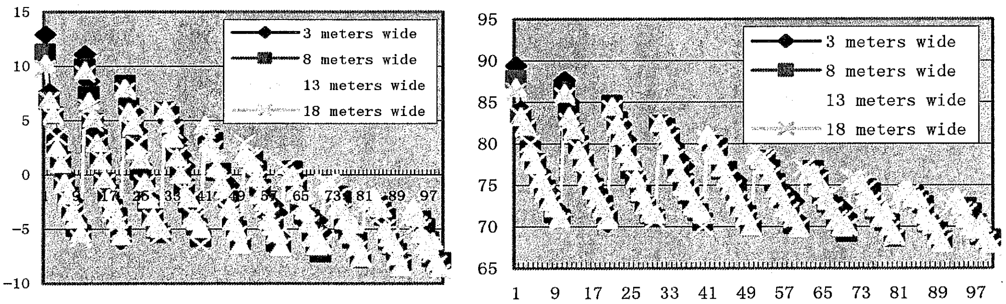
3. It can be seen from Figure35 that, just like the phenomenon described in assumption one, the values of EDT, T15 and T30 have really increased with gradually increasing width of the stage. But their increments are very small, the average increment is only about 0.15 seconds. The reason of this phenomenon have already been mentioned in assumption one.



(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 36. Color pictures and curve charts of C80, D50 and STI

4. It can be seen from Figure36 that, just like the phenomenon described in assumption one, the values of D50, C80 and STI decrease when the width of the stage gradually increases. But the decrease extent is very small, all the values of D50, C80 and STI are almost unchanged. The reason of this phenomenon has already been mentioned in assumption one.

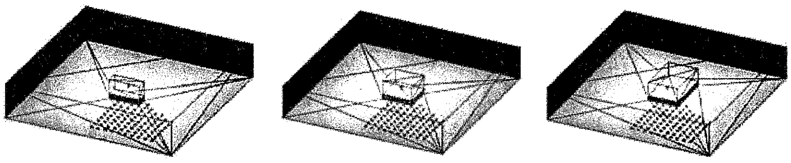


(a) (b)

Figure 37. Curve charts of G (a. Sum) and SPL (b. Sum)

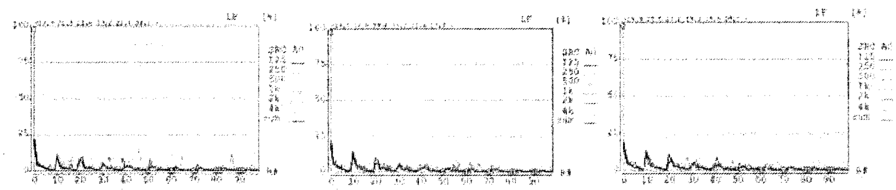
5. It can be seen from Figure 37 that, just like the phenomenon described in assumption one, the values of G and SPL decrease when the width of the stage gradually increases. But the decrease rate of the value is very small, all the values of G and SPL are almost unchanged. The reason of this phenomenon has already been mentioned in assumption one.

Assumption four: keeping the abstract two-side-view stage of forward-and-backward style at a constant width of 9 meters, the frame of proscenium arch at a constant height of 4 meters and the pedestal at a constant height of 1.5 meters, when the depth of the abstract stage increased from 3 meters to 13 meters in a single increment of 5 meters (Figure 38), the following conclusions can be drawn by analyzing the charts and pictures below:



(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

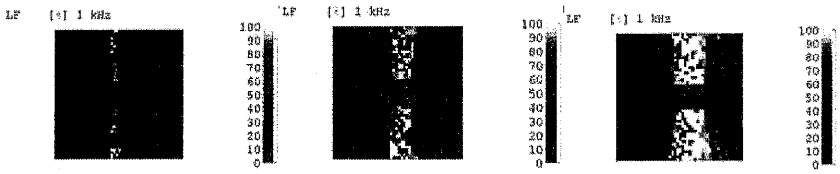
Figure 38. The gradual change in the depth of the abstract stage



(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

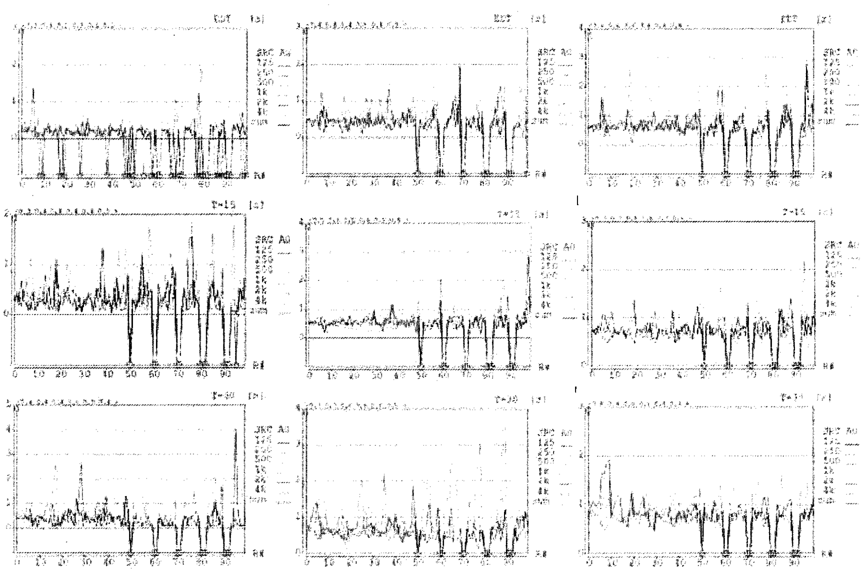
Figure 39. Curve charts of LF

1. It can be seen from Figure39 that, just like the same phenomena described in assumption two, the values of LF in the audience region of the theatre are very low, the highest value not exceeding 25, each overall average is below 10. In addition, the trend of the values of LF along the longitudinal direction of the audience area is that the further away from the abstract stage the receiver point is, the smaller the corresponding value of LF. Furthermore, the Figure39 also shows that when the depth of the abstract stage gradually increases, as the same phenomena described in assumption two, the variation range of the value of LF essentially unchanged, it still remains in the range of 0 to 25. That means the amount of the total energy of the lateral reflections of the audience area of the theatre essentially unchanged. As shown in the Figure40 below, only the amount of the energy of lateral reflections on the back of the stage becomes larger along with the increasing depth of the stage. All the reasons of these phenomena have been mentioned above.



(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep
Figure 40. Color pictures of LF

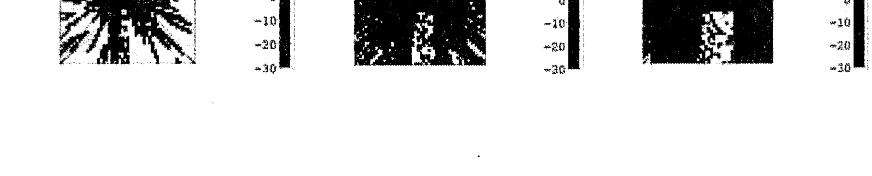
2. It can be seen from Figure 40 that, just like the same phenomena described in assumption two, when the depth of the stage gradually increases, the coverage of the lateral reflections in the audience area almost stays the same. Meanwhile, there is an inconspicuous ">" symbol-like flare in the color pictures of energy distribution of lateral reflections in the audience area. Both phenomena can be easily explained by the principles of geometrical acoustics.

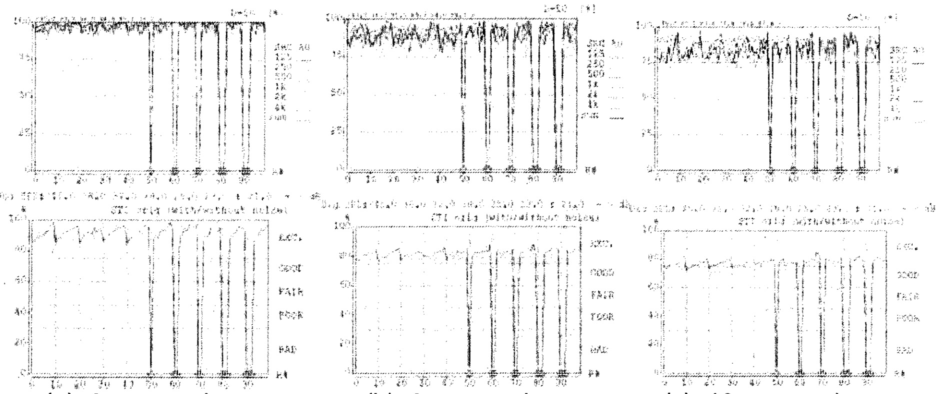


(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep
Figure 41. Curve charts of reverberation time

3. It can be seen from Figure41 that the values of EDT, T15 and T30 have really increased with gradually increasing depth of the stage. Just like the phenomenon described in assumption two, the rates of increase of the value of EDT, T15 and T30 here are more evident than that in assumption three, some increments of their values even close to 1 second. The reason of this phenomenon has been mentioned above.

4. It can be seen from Figure42 that, just like the phenomenon described in assumption two, the values of D50, C80 and STI decrease when the depth of the stage gradually increases. And the rates of decrease of the value of D50, C80 and STI here are more evident than that in assumption three. The reason of this phenomenon has also been mentioned above.

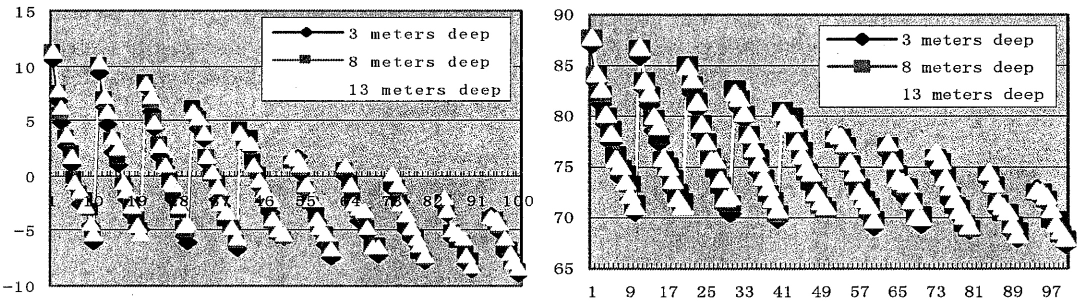




(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 42. Color pictures and curve charts of C80, D50 and STI

5. It can be seen from Figure 43 that, different from the phenomenon described in assumption two, the values of G and SPL almost stays constant when the depth of the stage is gradually increased. This is because comparing with the stage of one-side-view form of photo-frame style, the stage of two-side-view form of forward-and-backward style does not have a back wall. So, in the process of changing the depth of the stage, the distance between the receiver points and two gable walls, roof and surface of the stage also stays the same. Therefore, the amount of the reflected sound energy gained by the receiver points and provided by these surfaces of the stage is almost unchanged. Consequently, the value of G and SPL of the audience area of the theatre is almost unchanged.

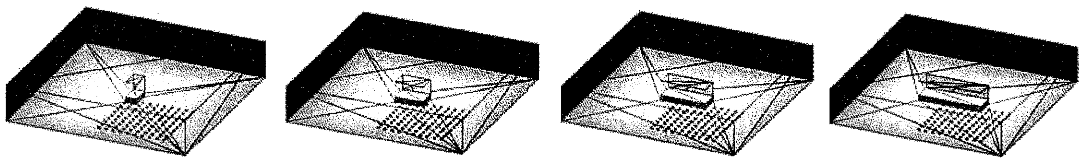


(a) (b)

Figure 43. Curve charts of G (a. Sum) and SPL (b. Sum)

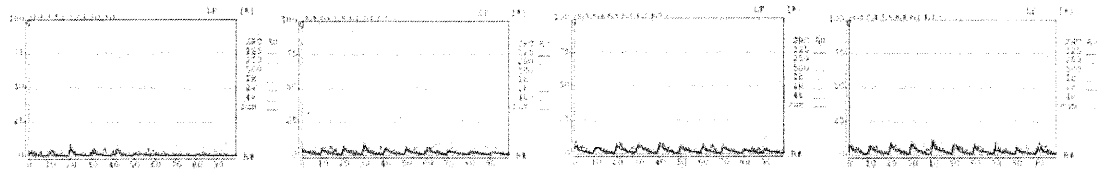
3.3 The Simulation and Analytical Results of the Stage of Three-Side-View Form of Extended Style

Assumption five: keeping the abstract three-side-view stage of extended style at a constant depth of 5 meters, the frame of proscenium arch at a constant height of 4 meters and the pedestal at a constant height of 1.5 meters, when the width of the abstract stage increased from 3 meters to 18 meters in a single increment of 5 meters (Figure 44), the following conclusions can be drawn by analyzing the charts and pictures below:



(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 44. The gradual change in the width of the abstract stage

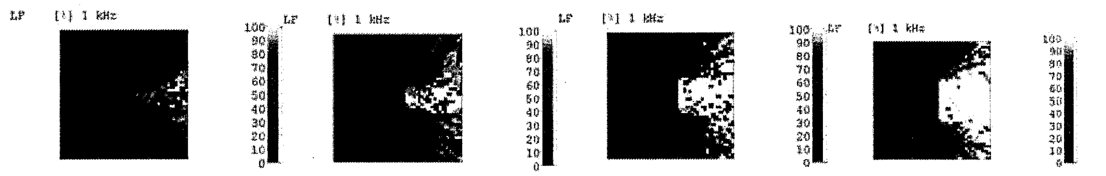


(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 45. Curve charts of LF

1. It can be seen from Figure 45 that, the values of LF of the stage of three-side-view form of extended style are significantly lower than that of the two types of stage mentioned above, the maximum value not exceeding 10, the overall averages of the value are all below 3, or even close to 0. This is because that, comparing with the two types of the stage above, both sides of the stage of three-side-view form of extended style without two gable walls are open, the lateral reflection sound energy of this type of stage is accordingly reduced significantly. In addition, it is the same as the phenomenon of two types of stage mentioned above, the trend of the values of LF along the longitudinal direction of the audience area is also that the further away from the abstract stage the receiver is, the smaller the corresponding value of LF. This is because, at this time the lateral reflection sound energy of the audience area of this type of theatre is mainly provided by the back wall of the stage, the further away from the back wall, the lower lateral reflection sound energy.

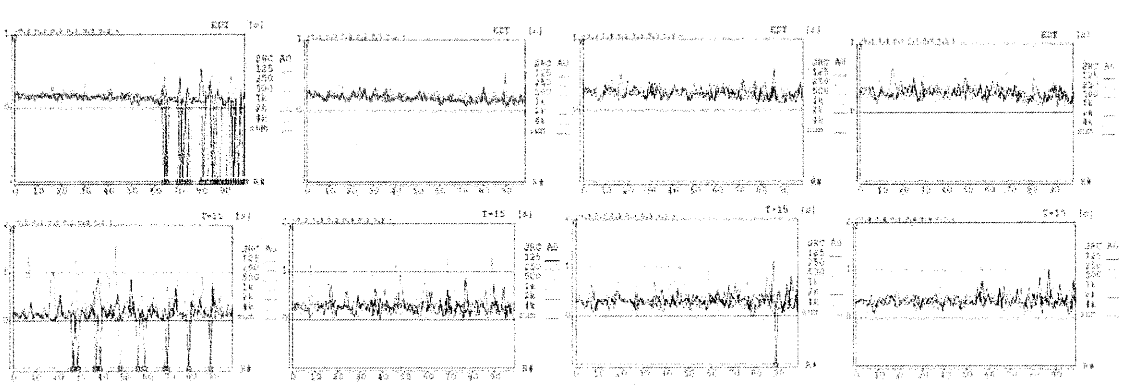
2. Figure 45 also shows that, it is different from the two types of stage above, with the gradually increasing width of the abstract stage here, the variation range of the value of LF is also enlarged. But the increasing range is not large. This is because, comparing with the two types of stage above, although the stage of three-side-view form of extended style loses two gable walls to provide lots of lateral reflection energy, its back wall itself can still provide less lateral reflection energy to the audience area. Gradually increasing width of the stage leads to gradually increasing area of the back wall of the stage. Therefore, the lateral reflection energy provided by the back wall of the stage increases along with the gradually increasing width of the stage.

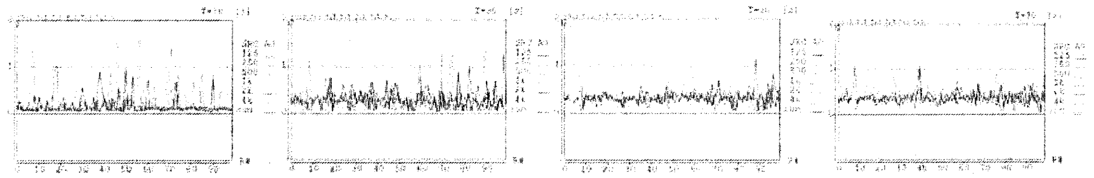


(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 46. Color pictures of LF

2. It can be seen from Figure 46 that, just like the phenomena described in assumption one and three, when the width of the stage gradually increases, the coverage of the lateral reflections in the audience area is also enlarged. Meanwhile, there is an inconspicuous ">" symbol-like flare in the color pictures of energy distribution of lateral reflections in the audience area. Both phenomena here can be easily explained by the principles of geometrical acoustics.

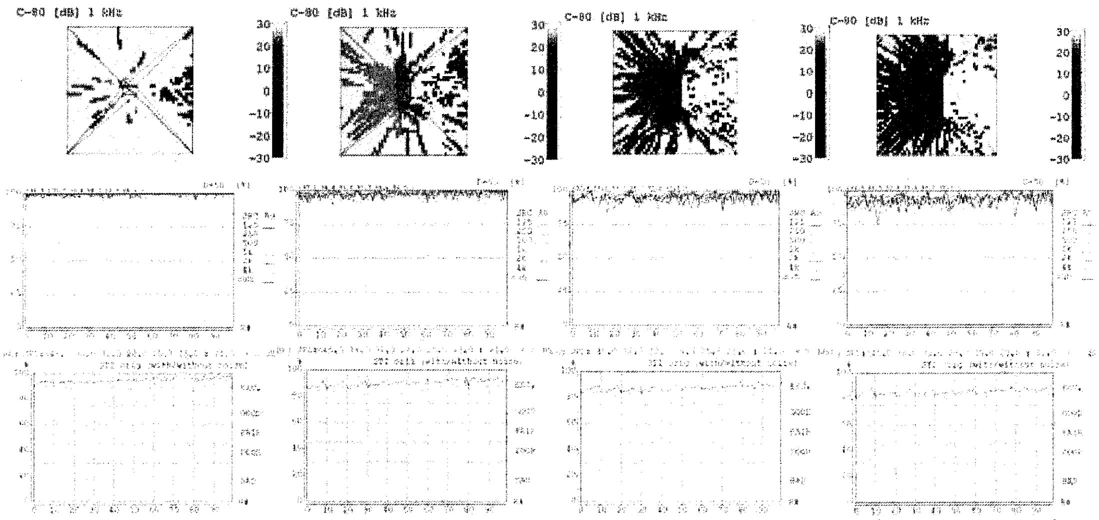




(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 47. Curve charts of reverberation time

3. It can be seen from Figure47 that, just like the phenomenon described in assumption one and three, the values of EDT, T15 and T30 have really increased with gradually increasing width of the stage. But their increments are very small, the average increment is only about 0.15 seconds. The reason of this phenomenon have already been mentioned in assumption one.

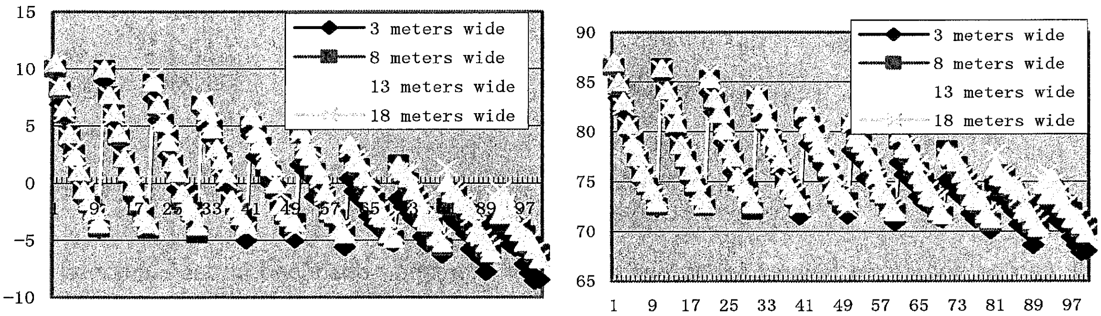


(a). 3 meters wide (b). 8 meters wide (c). 13 meters wide (d). 18 meters wide

Figure 48. Color pictures and curve charts of C80, D50 and STI

4. As shown in the Figure48, it is the same as the two types of stage above, the value of D50, C80 and STI here decreases with the gradually increasing width of the stage. While, it is different from the two types of stage above, the decreasing range of all these parameters of the stage of three-side-view form of extended style is larger than that of the two types of stage above. The decreasing reason of these parameters of two types of stage above has been mentioned. That is mainly due to the impact of reverberation sound energy. Although the gradually increasing width of the stage here also leads to the increasing reverberation sound energy, the actual increment is still very small. It is not powerful enough to reduce the value of D50, C80 and STI significantly. The main reason of the value of these parameters significantly reduced is due to the gradually increasing lateral reflection sound energy which is provided by the back wall of the stage. Therefore, combined with the increasing reverberation sound energy, the dramatically increasing lateral reflection sound energy leads to the apparently decrease of the value of all these parameters.

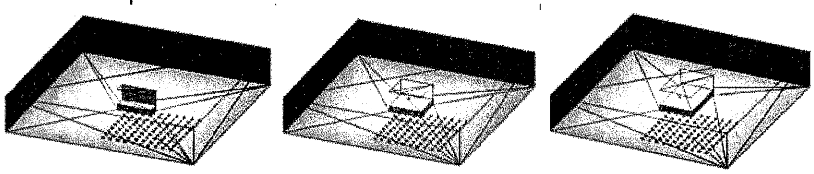
5. As shown in the Figure 49, it is different from the two types of stage above, with the gradually increasing width of the stage, the value of SPL and G here almost stays the same. This is because, comparing with the two types above, the stage of three-side-view form of extended style does not have two gable walls. Keeping the depth of the stage and height of the proscenium the same, the distance between receiver point and back wall, roof and surface of the stage accordingly stays the same. Therefore, the almost constant reflected sound energy provided by these boundaries leads to the nearly constant value of SPL and G.



(a) (b)

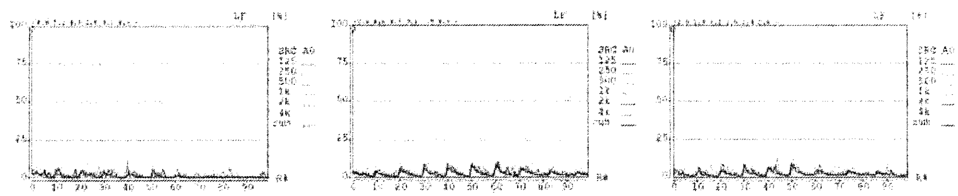
Figure 49. Curve charts of G (a. Sum) and SPL (b. Sum)

Assumption six: keeping the abstract three-side-view stage of extended style at a constant width of 9 meters, the frame of proscenium arch at a constant height of 4 meters and the pedestal at a constant height of 1.5 meters, when the depth of the abstract stage increased from 3 meters to 13 meters in a single increment of 5 meters (Figure 50), the following conclusions can be drawn by analyzing the charts and pictures below:



(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 50. The gradual change in the depth of the abstract stage



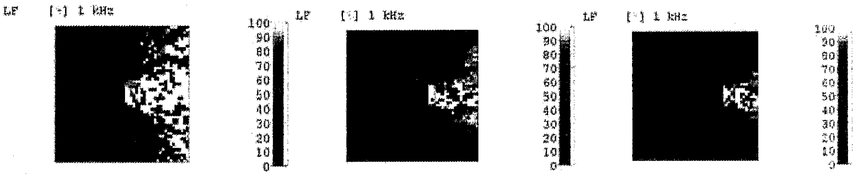
(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 51. Curve charts of LF

1. It can be seen from Figure 51 that, just like the phenomenon described in assumption five, the values of LF are very low, the maximum value not exceeding 10, the overall averages of the value are all below 3, or even close to 0. In addition, the trend of the values of LF along the longitudinal direction of the audience area is also that the further away from the abstract stage the receiver is, the smaller the corresponding value of LF. The reasons of these phenomena have already mentioned above. Furthermore, Figure 51 also shows that when the width of the abstract stage gradually increases, just like the phenomenon described in assumption two and four, the variation range of the value of LF essentially unchanged, it still remains in the range of 0 to 10. That means the amount of the total energy of the lateral reflections of the audience area of the theatre essentially unchanged. This is because the width of the stage and the height of the proscenium stay the same, no matter what the depth of the stage changes, the area of the back wall of the stage maintains constant. With the gradually increasing depth of the stage, the lateral reflection sound energy provided by the back wall is accordingly unchanged.

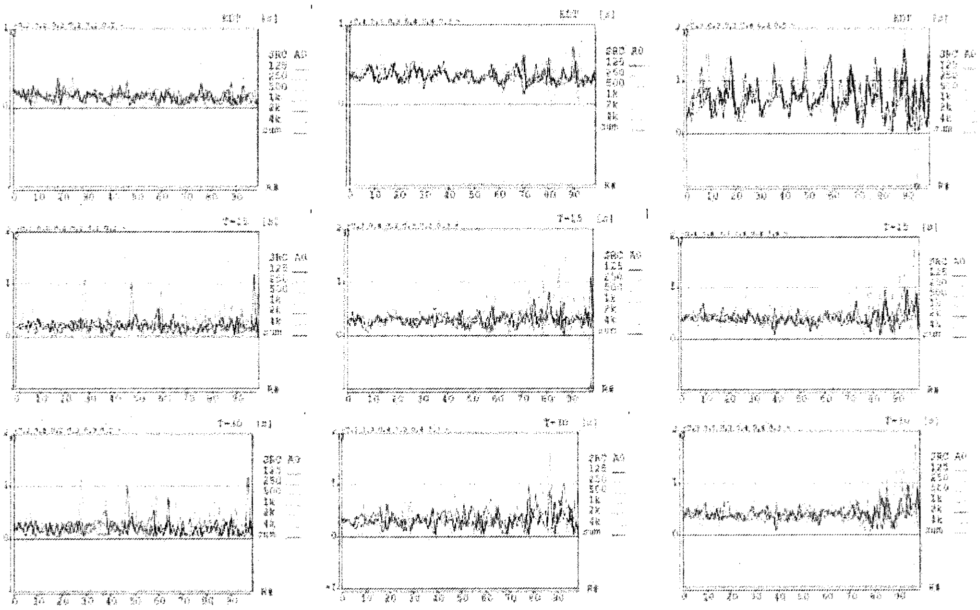
2. As shown in the Figure52, it is different from the two types of stage above, with the gradually increasing depth of the stage, the coverage of the lateral reflections of the abstract three-side-view stage of extended style in the audience area becomes small. In addition, the same as the two types of stage above, there is an inconspicuous ">" symbol-like flare in the color pictures of energy

distribution of lateral reflections in the audience area. Both phenomena can be easily explained by the principles of geometrical acoustics.



(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 52. Color pictures of LF



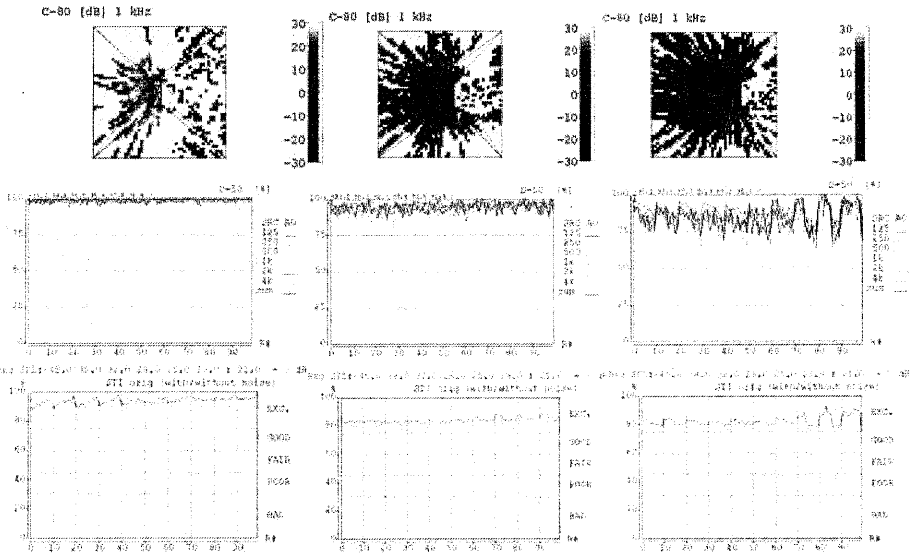
(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 53. Curve charts of reverberation time

3. As shown in the Figure53, it is different from the two types of stage above, although the values of EDT, T15 and T30 increase with the gradually increasing depth of the stage, the increments of the value is smaller than those of two types of stage. On the contrary, it is similar to the phenomenon of assumption five, the increments here are around 0.15s. This is because the abstract three-side-view stage of extended style does not have two gable walls. With the gradually increasing depth of the stage, the area of two open sides on both sides of the stage also increases. It directly leads to the increase of the degree of energy loss of the reverberant sound. Therefore, although the volume of the stage increases gradually, the actual increment of reverberant sound energy is not large. It leads that the increments of the value of EDT, T15 and T30 of the sound field of the theatre are also very small.

4. It can be seen from Figure54 that with the gradually increasing depth of the stage, the values of D50, C80 and STI decrease. And it is the same as the phenomenon described in assumption two and four, the decreasing ranges of the value of all these parameters are broadly apparent, namely the decrements are all large. As the reason mentioned above, in the same sound source condition, all these parameters mainly relates to the amount of the energy of the reverberant sound. It is different from the two types of stage above, with the gradually increasing depth of the stage, the area of two open sides on both sides of the stage also increases. It directly leads to the increase of the degree of energy loss of the reverberant sound. Therefore, with the gradually increasing volume of the stage, the actual increment of the reverberant sound energy is still small. By this reason, the decrement of the value of D50, C80 and STI should also be small. Why does it appear completely

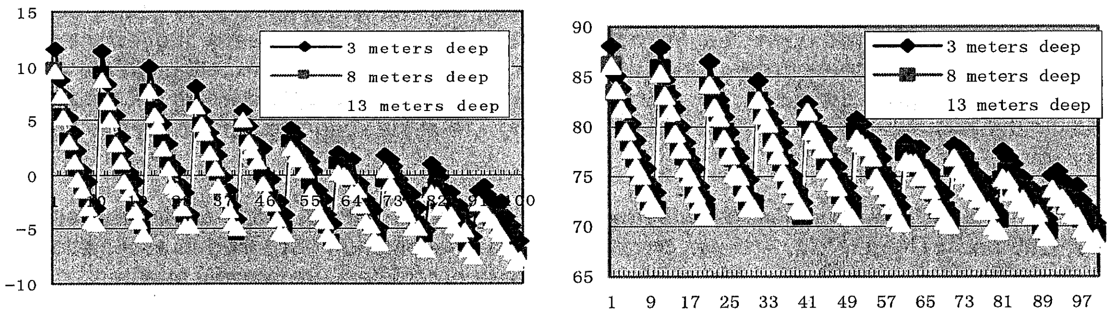
different phenomenon here? The main reason is caused by the lateral reflection energy of the stage. It can be obviously seen from the Figure52 that with the increasing depth of the stage, the directivity angle of the lateral reflection is gradually becomes small. Especially with the depth increased from 3 meters to 8 meters, the decreasing directivity angle of the lateral reflection leads to distinct increasing range of the lateral sound reflection energy spreading to the audience area. It consequently results the distinct decreasing value of D50, C80 and STI.



(a). 3 meters deep (b). 8 meters deep (c). 13 meters deep

Figure 54. Color pictures and curve charts of C80, D50 and STI

5. As shown in the Figure55, it is the same as the phenomenon described in assumption two but different from the phenomenon described in assumption four, with the gradually increasing depth of the stage, the values of SPL and G of theatre decrease. This is because, comparing with the two types above, the stage of three-side-view form of extended style does not have two gable walls. Keeping the width of the stage and height of the proscenium the same, the distance between receiver point and roof and surface of the stage accordingly stays the same. The increase of the depth of the stage leads to the increase of the distance between the receiver points and the back wall of the stage. Therefore, the reflected sound energy gained by the receiver points and provided by the back wall of the stage correspondingly reduces. Consequently, the value of G and SPL of the audience area of the theatre decreases.



(a) (b)

Figure 55. Curve charts of G (a. Sum) and SPL (b. Sum)

4 CONCLUSIONS

Due to limitations on space, this paper focuses on discussing the acoustic impact of horizontal change of architectural form of the ancient Chinese stage, namely, studying the relationship between the width and depth of the stage and the acoustic parameters of theatre. While, discussing the acoustic impact of vertical change of architectural form of the ancient Chinese stage, which is studying the relationship between the width and depth of the stage and the acoustic parameters of theatre, was abandoned here.

In summary, for the stage of one-side-view form of photo-frame style, the dimensional change of the width of the stage mainly affects LF, G and SPL; while the dimensional change of the depth of the stage mainly affects EDT, T15, T30, C80, D50, STI, G and SPL. For the stage of two-side-view form of forward-and-backward style, the dimensional change of the width of the stage mainly affects LF, G and SPL; while the dimensional change of the depth of the stage mainly affects EDT, T15, T30, C80, D50 and STI. For the stage of three-side-view form of extended style, the dimensional change of the width of the stage mainly affects LF, C80, D50 and STI; while the dimensional change of the depth of the stage mainly affects LF, C80, D50, STI, G and SPL.

5 REFERENCES

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2. All the dramatic performance activities carved on the Dunhuang mural paintings shows that Buddha and actors all faced forward or lateral side. It seems to show that the actors did not face the most important audience——the Buddha. But I think it did not match the actual situation at the time. Because, in order to obtaining the best perspective for the viewers, the painter may deal with in this way.
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5. Because it is difficult to obtain the accurate dimension data of the architrave of proscenium, and some ornate decorative elements of the stage of the Ming and Qing dynasties, such as sparrow brace, often seem to be regarded as the visual element of the architrave of proscenium. The height to width ratio of the stage here was the only way for discussing.
6. In fact, the effective visual field of human eyes is about 180 degrees in horizontal direction, and about 120 degrees in vertical direction, which would indicate a best height to width ratio of the picture frame at 1:1.5. But the anamorphic wide-screen film system which dominated the film industry adopts height to width ratio of the picture frame at 1:2.35. In addition to increasing the area of screen, wide-screen film makes the audiences move their focal length frequently by stretching the picture frame. This may also the main reason of its visual impact.
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