
EXAMINATION OF COURTYARD DIMENSIONS AND PROPORTIONS IN UNIVERSITI TEKNOLOGI MALAYSIA BUILDINGS

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Abstract

The use of the courtyard as an architectural design element is applicable in almost all building typologies in all regions of the world due to its microclimatic potentials for passive and low energy architecture. But despite its abundant advantages, research effort towards its examination in buildings is very scarce. Therefore, this study examines the courtyard dimensions and proportions in Universiti Teknologi Malaysia (UTM) buildings such as the courtyard perimeter ratio, aspect ratio, height, and area. The methodology of this study is the use of a specification checklist which was developed for the study. Forty-six courtyards in thirty-two buildings were examined. The statistical description was used to interpret and analyzed data. The study revealed that most of the courtyards in UTM buildings were designed within the specification. The courtyard aspect ratio, perimeter ratio, and height are; 81, 94%, and 84% respectively. In conclusion, this study explains a research work that adds in the direction of understanding the courtyard designed dimensions and proportions characteristics in buildings in UTM. However, more future simulation studies of their microclimatic behavior are required so as to substantiate the findings of this study, and to give courtyard design recommendations to architects for future architectural design proposals.

Keywords: *Courtyard parameter; Design variants; UTM Building; Climate*

1.0 INTRODUCTION

The application of the courtyard as an architectural design element in buildings is not uncommon to Architects. It is a universal design element which has been put into practice long ago. In particular, contemporary buildings in UTM has experienced this concept and it has become an area of interest in recent times to scholars. This is perhaps due to its numerous benefits. According to Edwards *et al.* (2006), courtyard as a building component was initiated originally from the hot and dry climatic regions of the world. Thus, its application is most suitable in the tropics, even though it is applicable to all climatic regions. Abass *et al.* (2016) defined courtyard as a covered outside space but open to the element at its apex. Mishra & Ramgopal

(2013) also defined a courtyard an open room into the heavens, a square or rectangular in the sketch and bordered by a group of buildings or most important rooms. The definitions can go on and on. But the appropriate courtyard form supposed to vary from one climatic region to the other, even its location, for instance, having a courtyard in the middle of the architectural design may not do better in all climatic situations (Ghaffarianhoseini *et al.*, 2015).

Thus, adopting the courtyard form from the western states into the tropical region; the hot-dry climatic region in particular, rather than the original indigenous concept which is adaptable to the cultural, climatic and religious requirement of the people may be a mere deception. More so, many primordial courtyards in the Arab nations have elucidated a clear picture of a courtyard

designed based on the social, cultural and climatic requirements. The categories of the design requirements for instance; aspect ratio, height, orientation, exposure to the sky, nature of the wall components and much more were evolved to realize effective courtyard that responds to the human requirement for comfort in buildings (Berkovic *et al.*, 2012). This is important if the courtyard is to fulfill its functions.

The realization of the courtyard as an architectural design element is suitable in almost all building typologies in all the climatic zones due to its passive tendencies for low energy consumption in buildings. It has social, cultural, religious, and environmental usage. Despite its abundant advantages, research effort towards its examination in buildings in UTM is very scarce. Therefore, it is based on this note that this study examines courtyard dimensions and proportions such as the courtyard perimeter to height ratio, aspect ratio, height and area in courtyard buildings in UTM. The methodology of this study adopts Almhafdy *et al.* (2013) study approach but with some kind of modifications in terms of the variables.

A checklist was developed for the examination of 46 courtyards in 32 buildings. The literature related to this endeavour were used to develop the checklist. This paper is divided into five parts; the introduction, study background, methodology, findings and discussion, and the conclusion. This study is important not only to Architects but even to scholars as it has provided a background for future allied studies.

2.0 LITERATURE REVIEW

In architectural design, the courtyard as an element has been put into practice for many years particularly in housing design. Its application is justified due to its numerous benefits. In recent times, scholars have opined the benefits of the courtyard in order to elucidate its relevance in a building. These benefits include architectural benefits; social benefits, climatic benefits; cultural benefits; economic benefits; and the religious benefits (Almhafdy *et al.*, 2013a).

Courtyards were frequently used as a meeting area for specific functions such as

gardening, cooking, working, playing, sleeping, or even in some cases as places to keep animals (Edwards *et al.*, 2006).

The courtyard suitability for diverse functions may not be far from its location in the house layout (which varies from one group of culture to another). According to Antonio & Carvalho (2015), the importance of such a space was by their being located in central sites within the urban fabric or building surrounded by arcades and colonnades, paved, landscaped with water bodies, various plants, shade and light, they all played an important role in our social and working life. In terms of its contribution to good health, Antonio & Carvalho (2015) continue that the courtyard can be used as a place for facilitating the healing process due to its natural healing environment.

Courtyard dimensions and proportions contribute in a major way in modifying its climatic setting and thereby inducing the mental and physiological sensation of its end users. The rectangular and square are the most used courtyard form in buildings even though, there is no any particular form that is considered as the most suitable (Almhafdy *et al.*, 2013b). In architectural design, the courtyard is in rectangular or square form, but circular, curvilinear and other forms may evolve. The courtyard form can be adapted to by using the numerous eco-friendly aspects such as scenery, site limitations, building orientation, to generate new shapes, for instance; U, L, T or Y (Das, 2006; Reynolds, 2002). Also, the courtyard form can be fully enclosed, semi-enclosed or in some cases even two sided (Berkovic *et al.*, 2012).

Scholars have conducted studies on courtyard dimensions and proportions in recent times pointing to the fact that, the form can be manipulated to act as a microclimate modifier to the built environment. For instance, courtyard dimensions were found to be a key design requirement in a study on the archetypal rectangular courtyard form and its impact on the eco-friendly performance in the tropical region (Aldawoud, 2008). Tablada *et al.* (2005) studied and suggested that the courtyard dimensions and proportions are crucial and the entire envelope needed to be protected against extreme solar radiant heat and the penetration of dusty air as well as air movement which has a severe

consequence on thermal stress. Also, Ganem *et al.* (2014) revealed that the courtyard generated improved microclimatic condition; mostly when some design requirements for instance; orientation, proportions of courtyard and ventilation strategies are not ignored.

On courtyard perimeter and height ratio, Muhaisen (2006) research on 'The Effect of a Rectangular Courtyard Proportions at Four Different Climatic Locations' using the simulation method, the impact of courtyard parameter and height ratio, and orientation on shading effect was investigated. The appropriate courtyard elevation to obtain a good shading effect in summertime and wintertime was discovered to be at least nine meters in the hot-humid region, six meters in the hot-dry region and three meters in cold and temperate region. This suggests that higher elevations should be used for courtyards in warmer climatic regions while low elevation should be applicable for courtyards in the cooler climatic region.

Furthermore, Huang *et al.* (2014) revealed that the deeper form generates more shadow within the courtyard in summertime whereas narrow courtyard shape behaves well in wintertime. They suggested an annual calculating ratio. But, for the daylight, this recommendation is not applicable. The courtyard potential to act as a passive cooling element can be compared with a building composition in terms of airflow rate and pattern. Muhaisen *et al.* (2006b) concluded that for a reasonable performance throughout the whole year, courtyards with parameter and height ratio equal to or greater than five are recommended.

On courtyard aspect ratio, Fardeheb (2007) revealed that, if the ratio between the width and height (aspect ratio) of the courtyard were lower, a more constant temperature inside the court during the day making the courtyard a cooler place than the street outside should be expected. Also, Meir *et al.* (1995) concord that turbulence in wind speed and an increase in shading performance of a courtyard is directly proportional to the increase in aspect ratio. The study concludes that 0.5, 0.65 and above 0.65 ratios as the range for courtyard optimum environmental performance.

Courtyard orientation is also another design variant that seems to record very few literature.

However, scholars that have contributed in this regards include Antonio & Carvalho (2015), studied the impact of courtyard orientation on its environmental performance by using both experimental and simulation methods. The study reveals that increased height of courtyard walls will cause a reduction in the degree of air temperature in the courtyard as well as the rooms in a nearby location to the courtyard. On orientation, the study reveals less significance on air temperature but affects ventilation significantly as the enclose walls tend to block air free passage. Berkovic *et al.* (2012), continued that elongated east-west rectangular courtyard has the smallest portion of shade and consequently, not recommended for effective shading strategy for cooling. Almhafdy *et al.* (2013a), asserted that there is no evident record on verification of the most suitable courtyard orientation for its optimum environmental performance, although, there is a general believe that courtyard orientation with the elongated side facing the north to south direction is the best option.

According to Meir, *et al.* (1995), accurate orientation of courtyard can increase their thermal well-being; but, orienting it irrespective of solar angles and wind course may create thermal distress. But the setting of a building is considered in most cases by the orientation. The factors with direct impact on courtyard microclimatic behavior include; location of the sun, the direction of the wind, shading effect and radiant heat (Bagneid, 2006). All these factors are key to Courtyard orientation.

Courtyards enclosing walls varied from one region to the other. The variation is caused by the social, cultural economic and eco-friendly conditions. Even though the design remains analogous, the requirements of the design are determined by usage and location (Meir *et al.*, 2000). Wall enclosure can be defined as the summation of the courtyard components within the building. These components include; walls, doors, and windows. They play a significant role in the microclimate performance of the courtyard through natural ventilation strategies. They can also be influenced by opening or closing of the openings and by altering the wall to window ratio. According to Al-hemiddi & Al-saud (2001), insignificant cooling is observed when all

windows are closed. But, opened windows and doors improve natural ventilation in the courtyard. Other scholars (Muhaisen, 2006; Bagnied, 2006) have agreed that other preferences to look into when optimizing courtyard are the choice of the component material, color, and specifications.

3.0 METHODOLOGY

Information was derived from the literature on courtyard design variants and their effect on environmental behavior and used to generate a checklist. This methodology was adopted from Almhafdy *et al.* (2013), in a study on “Analysis of the Courtyard Functions and its Design Variants in the Malaysian Hospitals”, but few modifications were effected basically for the purpose of this study. The checklist was used in examining all the courtyard surveyed.

Table 1 (see appendix) illustrates the checklist that was used for the site survey. The checklist was derived according to the study background as presented in the literature of this study. Furthermore, roof shading device was added.

A total of 46 courtyards in 32 buildings in UTM were surveyed. The survey was conducted on 13th to 26th of the month of July 2016. Plates 1 to 10 (see appendix) are samples of some of the courtyards. The checklist was used for data collection as mentioned. Due to the favourable response, the whole exercise lasted for two weeks only as there were not major issues encountered. A comprehensive observation was carried out for each of the courtyards. The observation was based on the courtyards and its geometrical design conditions.

4.0 Results

The survey documented true data such as; the courtyard perimeter, length, width, area, and height. The aspect ratio and perimeter to height ratio were calculated and analysed. It was revealed that the use of courtyard is conversant in UTM buildings.

4.1 Courtyard Aspect Ratio

Figure 3 shows the approximate aspect ratio of the forty-six courtyard surveyed; two has less than 0.5 meters, six has 0.5 meters, twelve less than 0.65 meters, twenty-two has 0.65 meters, and four greater than 0.65 meters respectively. According to Muhaisen (2006) and Fardeheb (2007), the smaller aspect ratio will lead to more exposure to solar radiation and wind speed. Meir *et al.* (1995) concord that turbulence in wind speed and an increase in shading performance of a courtyard is directly proportional to the increase in aspect ratio. The study stressed that at an aspect ratio bellow 0.5 meters the courtyard is exposed to excessive solar radiation, at about 0.65 meters the wind velocity and shading are optimum, while greater than 0.65 meters will lead to a very deep courtyard with little or no ventilation effect at all. The study concludes that 0.5 meters, 0.65 meters and above 0.65m ratios as the range for courtyard optimum environmental performance analysis.

Therefore, from the result, it signifies that 22 (equivalent to 48%) courtyards have the aspect ratio for optimum environmental performance, 18 (equivalent to 33%) courtyards are not bellowed 0.5m, but only six (equivalent to 18%) courtyards are less than 0.5 meters and more than 0.65 meters.

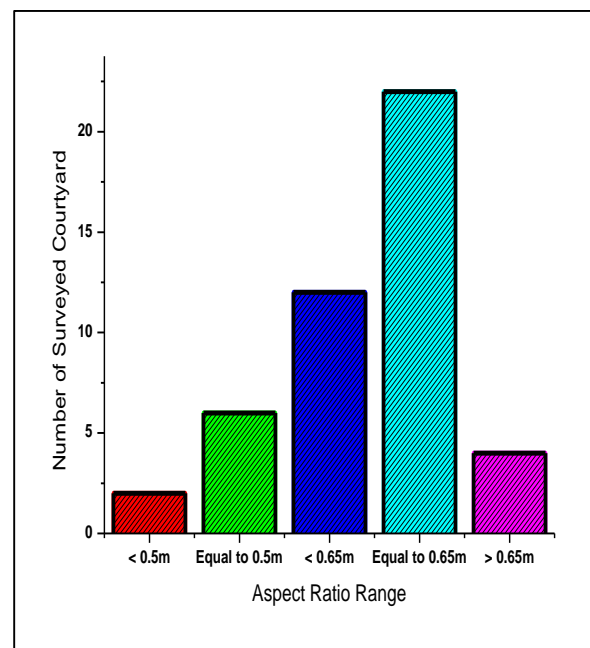


Figure 3: Showing the Distribution of Courtyards Aspect Ratio in UTM Buildings

4.2 Courtyard Aspect Ratio

Figure 4 shows the approximate courtyard perimeter ratio of the 46 courtyards surveyed; two courtyards have less than 5 meters, 16 has equal to 5 meters, while 28 has greater than 0.65 meters respectively. According to Muhaisen *et al.* (2006b), for a reasonable environmental performance throughout the whole year, courtyards with parameter and height ratio equal to or greater than five are recommended.

Consequently, from the result, it indicates that 44 (equivalent to 94%) courtyards have the recommended perimeter ratio for optimum environmental performance, while only two (equivalent to 6%) courtyards are less than 5 meters perimeter ratio.

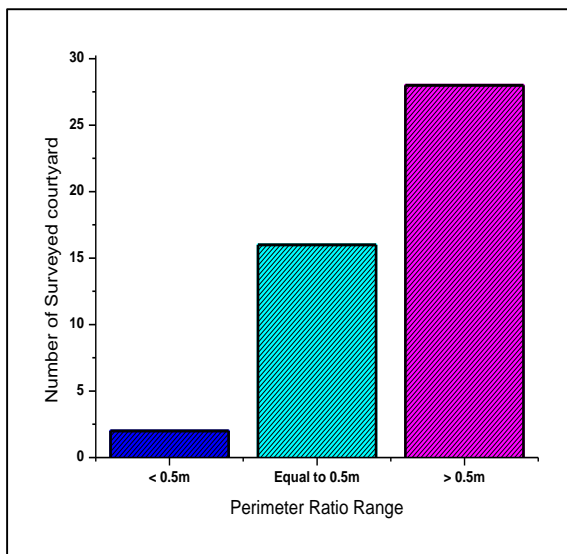


Figure 4: Showing a fully enclosed courtyard

4.3 Courtyard Height

Figure 5 reveals the approximate courtyard height of the 46 surveyed courtyard; six courtyards have less than 9 meters, eight has equal to 9 meters, while 32 has greater than 9 meters respectively. But according to Muhaisen (2006a), the appropriate courtyard elevation to obtain a good shading effect in summertime and wintertime was discovered to be at least 9 meters in the hot-humid region, 6 meters in the hot-dry region and 3 meters in cold and temperate region. This suggests that higher elevations should be used for

courtyards in warmer climatic regions while low elevation should be applicable for courtyards in the cooler climatic region.

Therefore, 9 meters courtyard height will be the appropriate benchmark for this study, as UTM is the case-study and is located in Johor Bahru, Malaysia which falls under the hot humid Muhaisen classification. Accordingly, from the result, it points to the fact that 40 (equivalent to 84%) courtyards have the recommended height of 9 meters for optimum environmental performance both in the winter or summer seasons, while only six (equivalent to 16%) courtyards are less than 9 meters height.

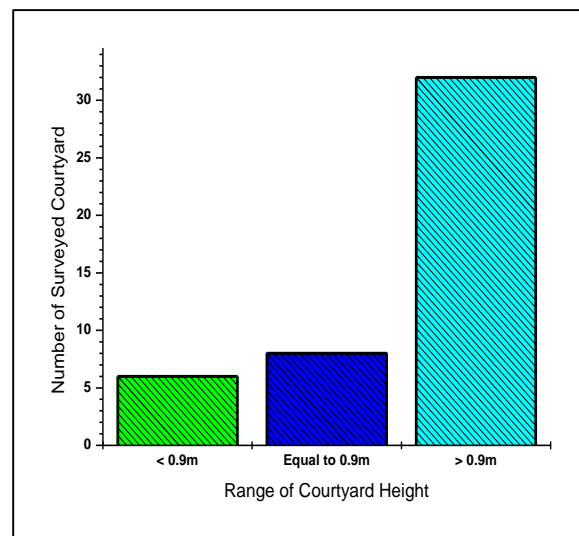


Figure 5: Showing the Distribution of Courtyard Height in UTM Buildings

4.3 Courtyard Area

Figure 6 reveals the approximate floor area of the 46 surveyed courtyard; one courtyard has an area within 0-30 meters square, 10 falls within 33-60 meters square, 12 falls within 61-120 meters square, 15 within 121-360 meters, and eight falls within 131-450 meters respectively. Studies on courtyard have pointed to the fact that, its dimensions and proportions are very critical if climate-responsiveness in the courtyard is required. For instance, Tablada *et al.* (2005) studied and suggested that the courtyard dimensions and proportions are crucial and they determine the courtyard perimeter ratio, as well as the aspect ratio. The literature has not yet

shown any standard floor area as a benchmark for assessment, however, since the surveyed courtyards have revealed 81%, and 94% courtyards aspect ratio and perimeter ratio as within the required range, then it can be concluded that the areas are equally satisfactory.

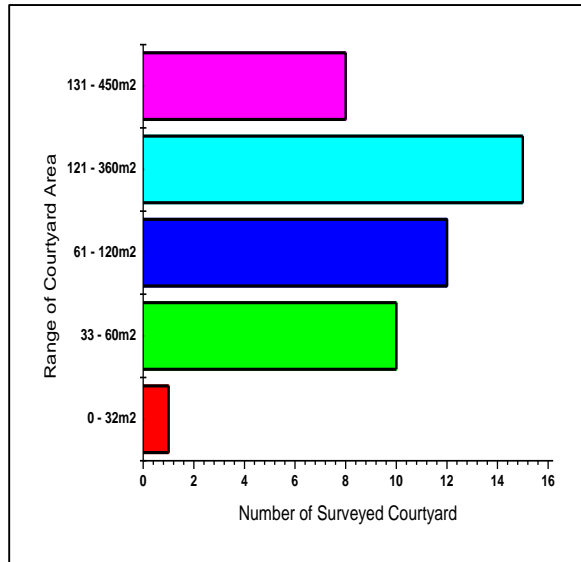


Figure 6: Showing Courtyards Area in UTM Buildings

Analytical Hierarchy Process (AHP) is developed by Thomas L. Saaty to incorporate both subjective and objective data into a logical hierarchical framework (Shen, 1997).

5.0 DISCUSSION

A robust bond between courtyard geometry, orientation, and environmental performance has been described in the literature. The courtyard geometry refers to its dimensions and proportions such as the courtyard perimeter ratio, aspect ratio, height, and area. Whereas the orientation refers to its cardinal location with reference to the geography of the globe. And the environmental performance connotes the climatic behavior of the courtyard as perceived by the end-users of such buildings and secondly to the building itself regarding the eco-thermal equilibrium with the built environment. Previous studies that have noted the importance of these courtyard design variables includes; Tablada *et al.* (2005), Muhaisen (2006a), Muhaisen *et al.* (2006b),

Fardeheb (2007), and Meir *et al.* (1995).

However, Very little was found in the literature on the question of investigating how far existing courtyard buildings geometry and orientation has to concord to the research findings in this area. Therefore, this study set out with the purpose of measuring the dimensions and proportions of courtyards buildings such as the courtyard perimeter ratio, aspect ratio, height, and area.

The results of this study indicate that UTM courtyard buildings were designed consciously as most of the surveyed courtyards dimensions and proportions are within the specified range as revealed in the literature. This study did not notice any significant difference that could cause any serious climatic behavior of courtyards. On the question of the courtyard aspect ratio, 22 (equivalent to 48%) courtyards have the aspect ratio for optimum environmental performance, 18 (equivalent to 33%) courtyards has an average, while only 6 (equivalent to 18%) courtyards has poor aspect ratio. The most remarkable finding was that only six courtyard has worse aspect ratio. Also, this study produced results which corroborate the findings of a great deal of the previous work in this field (Fardeheb (2007) and Meir *et al.* (1995).

On courtyard perimeter ratio; 44 (equivalent to 94%) courtyards has the recommended perimeter ratio for optimum environmental performance, while only two (equivalent to 6%) courtyards has bad perimeter ratio. According to Muhaisen *et al.* (2006b), for a reasonable environmental performance throughout the whole year, courtyards with parameter and height ratio equal to or greater than five are recommended, and the result of this study is in agreement.

However, two courtyards have a very bad perimeter ratio. A possible explanation for this might be that only a few Malaysian architect will embark on their design scheme without conducting very thorough studies on the client brief, his requirement, and a very good case-study analysis. And this kind of approach to the architectural design profession should not be ignored on the basis of the architect having the feelings of much years of professional practice, but rather adhering to the logical architectural design procedure.

On courtyard height, the revealed that 40

(equivalent to 84%) courtyards have the recommended height for optimum environmental performance (both in the winter or summer seasons), while only six (equivalent to 16%) courtyards has poor height. It is encouraging to compare this result with the findings of Tablada *et al.* (2005) which suggested that the courtyard height is crucial to its climatic behavior. Muhaisen (2006a) also revealed that the appropriate courtyard elevation to obtain a good shading effect in summertime and wintertime was discovered to be at least 9 meters in the hot-humid region, 6 meters in the hot-dry region and 3 meters in cold and temperate region. This suggests that higher elevations should be used for courtyards in warmer climatic regions while low elevation should be applicable for courtyards in the cooler climatic region.

And in the courtyard area, the finding supports previous research into this brain area which links the courtyard length and width (Muhaisen, 2006b). Surprisingly, the literature has not yet shown any standard floor area as a benchmark for assessment, however, since the surveyed courtyards have revealed 81%, and 94% courtyards aspect ratio and perimeter ratio as within the required range, then it can be concluded that the areas are equally satisfactory because the length, width, and height revolved around the perimeter and aspect ratio.

Finally, the findings of this study have important implications for architects and the architectural design of courtyard buildings. The major implication is the possibility that if architects of the twenty-first century will agree to maintain their approach to the architectural design of courtyard buildings which is based on a logical analysis of the client brief in relation to good case-study analysis of existing courtyard buildings design by older architects, then future courtyard buildings will not largely depend on the active means for attaining optimum thermal performance.

One of the major issues that emerge from these findings is if the passive design strategy (the use of the appropriate courtyard geometry in buildings) is celebrated by architects in their architectural design, then we can be certain that our built environment will not constitute a nuisance but rather, will be a positive agent of mitigating the present environmental challenges

such as; greenhouse gas emission and global warming. In conclusion, more studies on UTM courtyard buildings in terms of their microclimatic behavior is required so as to have a holistic appraisal, and this study could be used as background to support such explorations.

6.0 CONCLUSION

This study explains a research work that adds in the direction of understanding the characteristics of courtyards in UTM. The findings revealed that the courtyard is a common architectural element used in UTM buildings. It shows that 22 (equivalent to 48%) courtyards have the aspect ratio for optimum environmental performance, 18 (equivalent to 33%) courtyards has an average, while only 6 (equivalent to 18%) courtyards has poor aspect ratio. On perimeter ratio; 44 (equivalent to 94%) courtyards has the recommended perimeter ratio for optimum environmental performance, while only two (equivalent to 6%) courtyards are short of the range.

The courtyard height reveals 40 (equivalent to 84%) courtyards has the recommended height for optimum environmental performance (both in the winter or summer seasons), while only six (equivalent to 16%) courtyards has poor height. And in the courtyard area, 81%, and 94% percent of the courtyards aspect ratio and perimeter ratio are within the required range, then it can be concluded that the courtyards area are equally satisfactory. In conclusion, the findings of this study contribute towards the understanding of the true state of the courtyard buildings in UTM in regards to their geometrical proportions as compared to the literature.

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APPENDIX

Table 1: Risk Priority Matrix

Parameter	Result
Aspect Ratio	
Perimeter Ratio	
Area	
Height	
Length	
Perimeter	
Width	



Plate 1



Plate 2



Plate 3



Plate 4



Plate 5



Plate 6



Plate 7



Plate 8