ANNEXURE - 1

BASIC CALCULATIONS FOR AMÁAKRAMA.

1. Amáakrama.

In order to check the amáakrama few examples are taken on the garbhagáhas, doors, wall thickness and adhiséjas. The basic calculations are given in succeeding paragraphs.

2. Garbhagáhas. The details are given in table form:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Temple árikovil</th>
<th>Measurements (Width)</th>
<th>Proportions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>árikovil</td>
<td>Garbhagáha</td>
</tr>
<tr>
<td>1</td>
<td>ári Sankara Narayana Temple, Ramanthali</td>
<td>1096cm</td>
<td>535cm</td>
</tr>
<tr>
<td>2</td>
<td>ári Subramanya Swami Temple, Payyannur.</td>
<td>1090cm</td>
<td>472cm</td>
</tr>
<tr>
<td>3</td>
<td>ári áiva Temple, Venniyur.</td>
<td>535cm</td>
<td>268cm</td>
</tr>
<tr>
<td>4</td>
<td>ári Maha áiva Temple.</td>
<td>470cm</td>
<td>276cm</td>
</tr>
<tr>
<td>Sl. No</td>
<td>árikovil</td>
<td>Prísda</td>
<td>Door Height</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
<td>ári Tali áiva Temple,</td>
<td>832 cm</td>
<td>174 cm</td>
</tr>
<tr>
<td></td>
<td>Nedumpura</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>ári Ayyappa Temple,</td>
<td>198 cm</td>
<td>125 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Temple Location</td>
<td>Height</td>
<td>Width</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>3</td>
<td>Maha¿iva Temple, Triprangod</td>
<td>470cm</td>
<td>170cm</td>
</tr>
<tr>
<td>4</td>
<td>ári á¡sta Temple, Panjal</td>
<td>245cm</td>
<td>133cm</td>
</tr>
<tr>
<td>5</td>
<td>ári Ayyappa Temple, Muttichur</td>
<td>236cm</td>
<td>112cm</td>
</tr>
</tbody>
</table>

The proportions of door widths to heights nearly agree with am¿akrama. The widths of door proportionate to the widths of pr¡s¡das vary from 1/8\(^{th}\) to 1/4\(^{th}\). The sizes of doors appear to have considered the convenience of entry/exist of persons.
4. **Wall Thickness.** The details are as under:

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>árikovil</th>
<th>Prśita width</th>
<th>Wall thickness</th>
<th>Proportions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ári Vamanamurthi Temple, Mevallore.</td>
<td>846cm</td>
<td>55cm</td>
<td>Nearly 1/16&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>ári Dharmaśasta Temple, Arattupuzha.</td>
<td>580cm</td>
<td>37cm</td>
<td>Nearly 1/16&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>ári Ayyappa Temple, Muttichur.</td>
<td>236cm</td>
<td>37cm</td>
<td>Nearly 1/6&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>ári áasta Temple, Panjal.</td>
<td>245cm</td>
<td>32cm</td>
<td>Nearly 1/8&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>ári áiva Temple, Venniyur.</td>
<td>535cm</td>
<td>46cm</td>
<td>Nearly 1/12&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>ári Maha áiva Temple, Mannur.</td>
<td>975cm</td>
<td>45cm</td>
<td>Nearly 1/22&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Some of the wall thickness agrees with the proportions of $1/8$th to $1/16$th where as some are different.

5. *Adhiṣṭṭna*. The details are given below:

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>árikovil</th>
<th>Prṣeda width</th>
<th>Height of Adhisṛṇa</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ári Tali áiva</td>
<td>832 cm</td>
<td><em>Pancavarga</em> type.</td>
<td>Nearly agree with</td>
</tr>
<tr>
<td></td>
<td>temple,</td>
<td>(11 kol pariśā)</td>
<td>Height=148 cm. Theoretically</td>
<td>the theoretical</td>
</tr>
<tr>
<td></td>
<td>Nedumpura.</td>
<td></td>
<td><em>adhisṛṇa</em> height=24+28=52a=2 kol1.33</td>
<td>height</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Temple Location</td>
<td>Theoretical Height</td>
<td>Actual Height</td>
<td>Comment</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>--------------------</td>
<td>---------------</td>
<td>---------</td>
</tr>
<tr>
<td>2</td>
<td>Narayana Temple, Ramanthali</td>
<td>$1096$ cm ($15 \text{ kol pari} \AA$)</td>
<td>$116$ cm</td>
<td>Less than theoretical height.</td>
</tr>
<tr>
<td>3</td>
<td>Mahadeva Temple, Trikadiyur</td>
<td>$490$ cm ($7 \text{ kol pari} \AA$)</td>
<td>$98$ cm</td>
<td>Less than theoretical height.</td>
</tr>
<tr>
<td>4</td>
<td>Áiva Temple, Veniyur</td>
<td>$535$ cm ($7 \text{ kol pari} \AA$)</td>
<td>$108$ cm</td>
<td>Nearly agrees</td>
</tr>
<tr>
<td>5</td>
<td>Áiva Temple, Elannummal</td>
<td>$532$ cm ($7 \text{ kol pari} \AA$)</td>
<td>$96$ cm</td>
<td>Height is less</td>
</tr>
<tr>
<td>6</td>
<td>Áṣṭa Temple, Panjal</td>
<td>$245$ cm ($3 \text{ kol pari} \AA$)</td>
<td>$78$ cm</td>
<td>Nearly agree</td>
</tr>
</tbody>
</table>

Some of the adhisññas agree with the theoretical proportions where as some are slightly different especially in bigger ērikovals.
ANNEXURE -2

BASIC CALCULATIONS TO OBTAIN FACTOR OF SAFETY

1. In order to arrive at the factor of safety, few examples of walls, rafters and
basements are taken. Materials of high quality are considered. Factors of safety are
incorporated while working on allowable stresses. NBC 2005 chapter 3.3.1 has been taken
as the basis for working out the ultimate comprehensive strength of masonry. It is
compared with Civil Engineer's, Hand Book by P.N Khanna (Chapter-VII). The working
stresses of timber are taken from the text books 'Design of steel structures Vol.1 by
Ramachandra (Chapter 13). The basic assumptions of stresses are:

(a) Allowable compressive stresses:-

(i) Timber - 8N/mm² parallel to the grain

4N/mm² perpendicular to the grain

(ii) Mansory in Lime mortar 0.60N / mm²
(3) Consolidated soil - 0.40 N/ mm$^2$

And hard soil - 0.60 N/ mm$^2$

The roof is assumed to be having slope of 45°. The weight of roof including live load of 75kg/m$^2$ worked out came to be 1.6KN/m$^2$. The load on wall is assumed to have a minimum eccentricity of effective height divided by 500 + lateral dimension divided by 30 subjected to a minimum of 20mm as per SP16 (S&T), 1980.

The results of approximate calculations are given in table form below:

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>árikovil</th>
<th>Member</th>
<th>Actual stress</th>
<th>Allowable stress</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ári áankaranarayana Temple, Ramanthali. (Two storeyed)</td>
<td>Rafters</td>
<td>1.08N/mm$^2$</td>
<td>8N/mm$^2$</td>
<td>Hard Soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Masonry</td>
<td>0.2N/mm$^2$</td>
<td>0.6N/mm$^2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Foundation</td>
<td>0.10N/mm$^2$</td>
<td>0.6N/mm$^2$</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>ári Subramanya Swami Temple, Payyanur (Two storeyed)</td>
<td>Rafters</td>
<td>0.8N/mm$^2$</td>
<td>8N/mm$^2$</td>
<td>Consolidated soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Masonry</td>
<td>0.24N/mm$^2$</td>
<td>0.6N/mm$^2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Foundation</td>
<td>0.08N/mm$^2$</td>
<td>0.4N/mm$^2$</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>ári áiva temple, Mannur,</td>
<td>Rafters</td>
<td>1.26N/mm$^2$</td>
<td>8N/mm$^2$</td>
<td>Hard soil</td>
</tr>
<tr>
<td>Site Description</td>
<td>Material</td>
<td>Rafters Stress</td>
<td>Masonry Stress</td>
<td>Foundation Stress</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>----------------</td>
<td>---------------</td>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td>ári ájsta Temple, Panjal (Single storeyed)</td>
<td>Masonry</td>
<td>0.28N/mm²</td>
<td>0.25N/mm²</td>
<td>0.6N/mm²</td>
<td></td>
</tr>
<tr>
<td>ári ájsta Temple, Panjal (Two storeyed)</td>
<td>Foundation</td>
<td>0.28N/mm²</td>
<td>0.25N/mm²</td>
<td>0.6N/mm²</td>
<td></td>
</tr>
<tr>
<td>ári Harikanyaka Temple, Ariyannur, Near Guruvayoor (Two storeyed)</td>
<td>Rafters</td>
<td>0.94N/mm²</td>
<td>0.14N/mm²</td>
<td>8N/mm²</td>
<td></td>
</tr>
<tr>
<td>ári Harikanyaka Temple, Ariyannur, Near Guruvayoor (Two storeyed)</td>
<td>Masonry</td>
<td>0.14N/mm²</td>
<td>0.10N/mm²</td>
<td>8N/mm²</td>
<td></td>
</tr>
<tr>
<td>ári Harikanyaka Temple, Ariyannur, Near Guruvayoor (Two storeyed)</td>
<td>Foundation</td>
<td>0.10N/mm²</td>
<td>0.6N/mm²</td>
<td>8N/mm²</td>
<td></td>
</tr>
<tr>
<td>ári Mahjdeva Temple</td>
<td>Rafters</td>
<td>1.2N/mm²</td>
<td>0.21N/mm²</td>
<td>8N/mm²</td>
<td></td>
</tr>
<tr>
<td>ári Mahjdeva Temple</td>
<td>Masonry</td>
<td>0.21N/mm²</td>
<td>0.6N/mm²</td>
<td>8N/mm²</td>
<td></td>
</tr>
<tr>
<td>ári Mahjdeva Temple</td>
<td>Foundation</td>
<td>0.6N/mm²</td>
<td>0.6N/mm²</td>
<td>8N/mm²</td>
<td></td>
</tr>
</tbody>
</table>

Note: It is assumed that about 50% of the rafter’s sectional area is cut for decoration and fixing.

From the above it can be observed that the actual stresses in timber (rafters) is about 4 to 10 times less than the allowable stresses. In the case of masonry, the allowable
stresses are about 2 to 3 times the actual stress. The stresses in foundation are about half to one third of allowable stresses taking compacted earth at sub base in most of the cases.

The members are oversized and may be the sacrificial section considering the life of ērikovils to be many centuries and be durable against all detrimental effects. The points raised by engineers that high factors of safety are applied in the design of temple ērikovils appear to be true. In the case of one ērikovil given at Sl. No. 5 the unequal settlements and cracks in the basement were noticed. The sub soil might have undergone unequal settlement in this case resulting in settlement of foundation and development of cracks in the basement. Such developments are seldom found in the ērikovil structures.
LIST OF PERSONS INTERVIEWED/DISCUSSED WITH


   Cochin - 25.


5. Sri. Balan Achari B, Anugrah, Near Subramanyaswami temple, Payyannore,
   Kannur Dist.

6. Dr. Balagopal. T.S.Prabhu, Retd. Professor, N.I.T. Calicut, 'Srivalsam', Kiliyanad,
   Calicut Dist.


8. Dr. Benny Abraham, Head of Civil Department, CUSAT, Kochi - 22.

    Dist.


12. Dr. Dayalan, Supdt; Archeologist, Archeological Survey of India, Chennai Region, Chennai.


22. Sri. Harish Namboodiri, Paikattu Mana, Meppayur, Tanur, Malappuram Dist.


26. Late Sri. Iswaran Namboodiri, Vattapparambu Mana, Sasta Nagar, Trissur - 1.


29. Sri. Joseph C.J, Engineer, Chiraparambil, St. Antory Road, Kaloor, Kochi-17.


35. Sri. Krishna Mallan, Executive Engineer (Retd), Sarovaram, East Hill Road, Calicut.


Cochin - 25.


41. Sri. Krishnan Namboodiripad, Sankara Nilayam, (Kanipayoor), Kunnamkulam, Trichur Dist.


44. Sri. Kuttan Moosad, Thrikkandiyur, Thirur, Malappuram Dist.


46. Sri. Madhavan Namboodiri. V.E., Chief Priest, Nambiatharakhol Temple, Payyannur, Kannur Dist.

47. Prof. (Dr.) Mathew P.S., Professor, IIT, Chennai.

48. Prof. (Dr.) Mehar Prasad, Professor and Head of Department, IIT, Chennai.

50. Dr. Namboodiri. D.D; Kainikkara, Chandrathil Road, Edappally, Kochi-24.

51. Sri. Nandakumar, Elavally, Chittattukara, Trichur Dist.

52. Sri. Narayanan T.V, Asst. Executive Engineer (Retd.).


60. Sri. Narayanan Namboodiri, S., Puthillum, Chennithala P.O,

   Alleppey Dist.

61. Sri. Narayanan Namboodiripad, Kidangasser Mana,

   Thannisseri P.O, Trichur Dist.


   Temple, Thiruvalla, Panthanamthitta Dist.

63. Dr. Nair .R.P.R., Rajendu, Cheloor P.O, Trichur.

64. Dr. Neelakandan. C.M. Prof. and Head. Department of Vedic Studies, S.S.U.S,

   Kalady, Ernakulam Dist.

65. Sri. Neelakandan Namboodiri, Vatasseri Mana, Njarakkal P.O,

   Ernakulam Dist.


67. Sri. Padmanabhan Namboodiri, Narayana Mangalam, Melsanti, Sankara

   Narayana temple, Ramanthali P.O, Kannur Dist.


71. Dr. Parameswarn. M.P, Matamgarli Mana, Kottapuram, Trichur Dist.


73. Sri Paramewaran Namboodiripad. N.P. Nedumbal Tarananallore Mana, Tanisseri  P.O. Trichur Dist.

74. Sri. Parameswaran Nambnoodiripad, Vezheparambu Mana, Kumaranallore, Kottayam Dist.

75. Sri. Parameswaran Namboodiri, Kizhu Mundayoor, Peramangalam, Trissur Dist.

76. Sri. Paravoor Sridharan Tantrikal, Paravoor, Ernakulam Dist.

77. Sri. Prabhakaran Embranthiri, Chief Priest, Mahadeva temple, Venniyur, Malappuram Dist.
78. Sri. Prasanth Namboodiripad, Assistant Engineer, CDB, Puliyanur Mana, Aroor, Ernakulam Dist.


82. Sri. Raman Namboodiri, Perumbadathu Mana, Mannothi, Trichur Dist.

83. Sri. Radhakrishnan Moosad, Thirumangalam, Trippamgod, Malappuram Dist.


86. Sri. Raju Jose. N. Executive Engineer, PWRM, Ernakulam Dist.


89. Sri. Ramdas, Dept. of Civil Engineering, CUSAT, Kochi - 22.

90. Sri. Sachidanandan, Marottikkal, Elamakkara, Ernakulam Dist.

91. Late Sri. Sambhu Vadhyan Namboodiri, Ex. Sabarimala Melsanthi, Karanthath, Kannur Dist.


93. Sri. Sankaran Bhattathiripad, Paloor Mana, Paravoor, Ernakulam Dist.

94. Sri. Sankara Narayan, Chief Engineer. FEDO, Ernakulam Dist.

95. Sri. Sankara Narayanan Namboodiri, Kapplingat Mana, Nedumpura, Cheruthuruthy, Trichur Dist.

96. Sri. Sankaran Namboodiripad, Kalpuzha Mana, Triprangot P.O, Malappuram Dist.


100. Sri. Shivaprasad, Shivapuri, Kulakkat chali P.O, Malappuram Dist.

101. Sri. Subramanyam Namboodiri, Thevamkottillam, Poovarani, Pala, Kottayam Dist.

102. Sri. Sasilekumar, Manager, Mahadeva Temple, Vazhappally, Thiruvalla.

103. Sri. Sashipalan. S. Engineer, Sriniketan House, Arakuzha Road, Moovatupuzha, Ernakulam Dist.


106. Sri. Sridharan Namboodiri, Kizhakkilom, Korom, Kannore Dist.


108. Sri. Subramanyan Namboodiri, Thevankottillom, Meenachil, Pala, Kottayam Dist.


111. Sri. Sunil Kumar. K. Engineer, Coloth House, Kudayathoor P.O. Todupuzha.


114. Dr. Trivikraman. N.T., Menon Parambu Road, Edappally, Kochi - 24.


117. Sri. Unnikrishan Menon. N, Retd; Structural Engineer, 'Lakshmi', Vidya Nagar, Cochin University. P.O.

118. Smt. Valiyathampuratti, Thiruvannore Kovilakam, Thiruvannore, Kozhikode.


120. Dr. Vishnu Namboodiri, Velinjal Mana, Cheranallore, Ernakulam Dist.
121. Sri. Vasudevan Bhattathiripad, Thevayil Kuzhikkat Illom, Thukalasseri, Thiruvalla, Pathanamthitta Dist.

122. Sri. Vasudevan Namboodiri, Mahadeva Temple, Vazhappally, Thiruvalla, Pattanamthilla Dist.

123. Sri. Vasudevan Namboodiri, Kakkattu Mana, Korattikkara P.O., Kadavallore, Trichur Dist.


