# Appendix A
# Failure Risk Model

# Appendix A – Failure Risk Model

## A.1 Failure Risk Model

As the preceding sections have demonstrated there are many factors to consider in producing a successful natural stone paving design. A failure risk model has been developed to ensure that all of the elements of the design process have been considered correctly. The risk model can act as a check on the design. The aim of the model is to provide a rapid check on the suitability of the design for its intended setting. The model also considers some of the factors that are not quantified in the design process such as workmanship.

The risk assessment is essentially a parametric analysis in which the most significant parameters influencing the performance of natural stone pavements are considered. The calculation process employed in the model derives a value that has been termed the Natural Stone Paving Failure Index.

The model has been developed as part of the research project for SCOTS and based on the experience and knowledge of the project team. There are areas of the model that will become better defined as knowledge of the behaviour of natural stone pavements advances. However testing of the model with a range of current and past specifications has shown that it can provide a reliable indication of the risk of failure of a natural stone pavement. It must be stressed that this is a risk model and it distinguishes between high and low failure risk for natural stone pavements. It does not indicate that a pavement will or will not fail or when. By definition low risk events can occur and high-risk events may not occur.

## A.2 Parameters

The current model is restricted to considering the parameters that have the greatest significance in terms of the performance of natural stone pavements. As knowledge advances the model will be refined through better defining the influence of the existing parameter sets and by introducing additional parameters that have a lesser influence. The parameters considered in the model and how the values used in the model have been derived are discussed below.

## A.3 Resistance to Failure

This is a composite parameter in that the values for resistance to failure are derived from the relationships between stone element size, shape, texture and joint or bedding material strength. The design protocol presented in this guide outlines two distinct controls in terms of resistance to failure, joint controlled and bedding controlled. The type of control that is relevant to a given element is dependent upon its size and shape. Setts, cubes and blocks are joint controlled and tiles and flags are bedding controlled. The structure of the risk model reflects this. The resistance to failure parameter for blocks, setts and cubes is joint dominant with a subordinate contribution from bedding. For tiles and flags the bedding is dominant with a subordinate contribution from jointing. As a result the model will indicate that any design that does not exploit the natural support tendency of the elements involved is adopting a high-risk approach. In a flagged pavement it may be theoretically possible to compensate for bedding deficiencies with a very high performance joint material but the model will still indicate that this is a high risk solution.

## A.4 Formula and Tables

The following formula and tables detail the parameters to be used in the calculation of the Paving Failure Index.

### *A.4.1 Parameters for Stone Units, Joints and Laying Course and Laying Pattern*

The initial resistance to failure parameter value for cubes, setts and blocks is calculated as follows: -

Equation 4.1 $(A_p * S_t * J_s * P) + (0.1 * A_b * B_s * P) = R_j$

Where $A_p$ is the effective perimeter area parameter (Table 4.12, 4.13)
$A_b$ is the effective base area parameter (Table 4.16, 4.17)
$S_t$ is the element surface texture parameter (Table 4.21)
$J_s$ is the Joint strength parameter (Table 4.22)
$B_s$ is the bedding strength parameter (Table 4.23)
P is the laying pattern of the elements (Table 4.20)
$R_j$ is the Joint controlled failure resistance parameter

The initial resistance to failure parameter value for tiles and flagstones is calculated as follows: -

Equation 4.2 $(A_b * B_s * P) + (0.1 * A_p * S_t * J_s * P)= R_b$

Where $A_p$ is the effective perimeter area parameter (Table 4.14, 4.15)
$A_b$ is the effective base area parameter (Table 4.18, 4.19)
$S_t$ is the element surface texture parameter (Table 4.21)
$J_s$ is the Joint strength parameter (Table 4.22)
$B_s$ is the bedding strength parameter (Table 4.23)
P is the laying pattern of the elements (Table 4.20)
$R_b$ is the bedding controlled failure resistance parameter

The initial resistance to failure parameter value for cubes, setts and blocks in an unbound construction is calculated as follows: -

Equation 4.3 $(0.4 * A_p * S_t * J_s * P) + (0.6 * A_b * B_s * P) = R_{ju}$

Where $A_p$ is the effective perimeter area parameter (Table 4.12, 4.13)
$A_b$ is the effective base area parameter (Table 4.16, 4.17)
$S_t$ is the element surface texture parameter (Table 4.21)
$J_s$ is the Joint strength parameter (Table 4.22)
$B_s$ is the bedding strength parameter (Table 4.23)
P is the laying pattern of the elements (Table 4.20)
$R_{ju}$ is the Joint controlled failure resistance parameter for unbound pavements

The range of values for perimeter area and base area have been derived from geometric relationships for the different element types (see tables 4.12 to 4.19). The surface texture parameter values have been derived based on the findings of the experimental work conducted as part of this project see Table 4.21. The joint and bedding strength parameter values have been derived from a combination of the experimental work carried out from this project, parallel experimental work, reviews of existing schemes and existing relationships from materials science (Tables 4.22 and 4.23). The laying pattern parameter values have been derived from the experimental work carried out as part of this project, geometric relationships and reviews of the performance of existing schemes (Table 4.20).

## Table 4.12 Sett/ Cube Perimeter Area ($A_p$) Parameter Values

| *Sett / Cube Depth (mm)* | *Average Depth (mm)* | *Average Perimeter Area ($cm^2$) (1)* | *Parameter Value* |
|---|---|---|---|
| < 90 | 80 | 896 | 1 |
| 90 – 120 | 105 | 1323 | 0.68 |
| 120 – 150 | 135 | 1458 | 0.61 |
| 150 – 180 | 165 | 2178 | 0.41 |
| > 180 | 200 | 3200 | 0.28 |

Notes

(1) Effective combined perimeter of sets / cubes based on a tyre contact area of 26cm by 23cm and a grid pattern.

## Table 4.13 Block Perimeter Area ($A_p$) Parameter Values

| | *Surface area ($cm^2$)* | *< 450* | *450 - 600* | *600 - 800* | *800 - 1000* | *> 1000* |
|---|---|---|---|---|---|---|
| | *Average area* | *375* | *525* | *700* | *900* | *1100* |
| *Depth (mm)* | *Average Depth (mm)* | *Parameter Values(1)* | | | | |
| *< 120* | *100* | 0.58 | 0.49 | 0.56 | 0.75 | 0.68 |
| *120 – 150* | *135* | 0.43 | 0.36 | 0.42 | 0.55 | 0.5 |
| *150 – 180* | *165* | 0.35 | 0.3 | 0.34 | 0.45 | 0.41 |
| *180 – 200* | *190* | 0.3 | 0.26 | 0.30 | 0.39 | 0.36 |
| *> 200* | *220* | 0.26 | 0.22 | 0.26 | 0.34 | 0.31 |

Notes

(1) based on ratios of combined perimeter for blocks with a tyre contact area of 26cm by 23cm and a grid pattern

## Table 4.14 Tile Perimeter Area ($A_p$) Parameter Values

| | *Surface area ($cm^2$)* | *< 300* | *300 - 450* | *450 – 600* | *> 600* |
|---|---|---|---|---|---|
| | *Average area* | *250* | *375* | *525* | *650* |
| *Depth (mm)* | *Average Depth (mm)* | *Parameter Values(1)* | | | |
| *< 40* | *35* | 2.02 | 1.65 | 1.40 | 1.26 |
| *40 – 50* | *45* | 1.57 | 1.29 | 1.09 | 0.98 |
| *50 – 60* | *55* | 1.29 | 1.05 | 0.89 | 0.8 |
| *> 60* | *70* | 1.01 | 0.83 | 0.70 | 0.63 |

Notes

(1) based on ratios of combined perimeter for blocks with a tyre contact area of 26cm by 23cm and a grid pattern

## Table 4.15 Flagstone Perimeter Area ($A_p$) Parameter Values

| | *Surface area ($cm^2$)* | *< 1100* | *1100 - 1400* | *1400 – 1700* | *1700 - 2000* | *> 2000* |
|---|---|---|---|---|---|---|
| | *Average area* | *1000* | *1250* | *1550* | *1850* | *2150* |
| *Depth (mm)* | *Average Depth (mm)* | *Parameter Values*[(1)] | | | | |
| *< 50* | *40* | 1.77 | 1.58 | 1.42 | 1.30 | 1.21 |
| *50 – 70* | *60* | 1.18 | 1.06 | 0.95 | 0.87 | 0.81 |
| *70 – 90* | *80* | 0.89 | 0.79 | 0.71 | 0.65 | 0.60 |
| *> 90* | *100* | 0.71 | 0.63 | 0.57 | 0.52 | 0.48 |

Notes

(1) based on ratios of combined perimeter for blocks with a tyre contact area of 26cm by 23cm and a grid pattern

## Table 4.16 Sets / Cubes Base Area ($A_b$)

| *Area ($cm^2$)* | *Average area* | *Elements in contact area* | *Composite area* | *Parameter value* |
|---|---|---|---|---|
| < 100 | 80 | 4 by 3 | 960 | 1.3 |
| 100 – 120 | 110 | 3 by 3 | 990 | 1.26 |
| 120 - 240 | 180 | 2 by 2 | 720 | 1.74 |
| 240 – 340 | 290 | 2 by 2 | 1160 | 1.08 |
| > 340 | 400 | 2 by 2 | 1600 | 0.78 |

## Table 4.17 Blocks Base Area ($A_b$)

| Area *($cm^2$)* | Average area | Elements in contact area | Composite area | Parameter value |
|---|---|---|---|---|
| < 450 | 375 | 2 by 2 | 1500 | 0.83 |
| 450 – 600 | 525 | 2 by 2 | 2100 | 0.60 |
| 600 – 800 | 700 | 2 by 1 | 1400 | 0.89 |
| 800 – 1000 | 900 | 1 | 900 | 1.39 |
| > 1000 | 1100 | 1 | 1100 | 1.14 |

## Table 4.18 Tiles Base Area ($A_b$)

| Area *($cm^2$)* | Average area | Elements in contact area | Composite area | Parameter value |
|---|---|---|---|---|
| < 300 | 250 | 2 by 2 | 1000 | 1.25 |
| 300 – 450 | 375 | 2 by 2 | 1500 | 0.83 |
| 450 – 600 | 525 | 2 by 2 | 2100 | 0.60 |
| > 600 | 650 | 2 by 1 | 1300 | 0.96 |

## Table 4.19 Flagstones Base Area ($A_b$)

| Area *($cm^2$)* | Average area | Elements in contact area | Composite area | Parameter value |
|---|---|---|---|---|
| < 1100 | 1000 | 1 | 1000 | 1.25 |
| 1100 – 1400 | 1250 | 1 | 1250 | 1.00 |
| 1400 – 1700 | 1550 | 1 | 1550 | 0.81 |
| 1700 – 2000 | 1850 | 1 | 1850 | 0.68 |
| > 2000 | 2150 | 1 | 2150 | 0.58 |

**Table 4.20 Patternation (P)**

| Pattern | Parameter |
|---|---|
| Grid | 1.0 |
| Stretcher | 0.8 |
| Bogan / Segmental Arch | 0.6 |

**Table 4.21 Texture ($S_t$)**

| Texture | Parameter |
|---|---|
| Cropped | 1 |
| Sawn | 2 |
| Sawn & Textured | 0.3 |

**Table 4.22 Joint Strength ($J_s$)**

| Joint Strength N/mm$^2$ | Average | Parameter |
|---|---|---|
| < 10 | 6 | 1 |
| 10 – 20 | 15 | 0.4 |
| 20 – 30 | 25 | 0.24 |
| 30 – 40 | 35 | 0.17 |
| > 40 | 50 | 0.12 |

**Table 4.23 Bed Strength ($B_s$)**

| Bed Strength N/mm$^2$ | Average | Parameter |
|---|---|---|
| < 10 | 6 | 1 |
| 10 – 20 | 15 | 0.4 |
| 20 – 30 | 25 | 0.24 |
| 30 – 40 | 35 | 0.17 |
| > 40 | 50 | 0.12 |

Note

Where semi dry bedding is used apply an additional multiplying factor of 3

## *A.4.2 Traffic Loading Parameter*

The risk model uses the same descriptive traffic loading categories as are outlined in Fig 4.1 and 4.2 in the design with the exception that an additional category is added to account for very heavily trafficked situations where there is regular and concentrated heavy vehicle usage e.g. busy bus route. The values for the traffic loading and site characteristics are based on the best judgement of the project team, traffic loading versus performance in rigid pavements and some of the guidance on traffic loading from modular pavement design. The values are outlined in Tables 4.24 and 4.25.

**Table 4.24 Traffic Parameters (T)**

| Loading Category | Parameter |
|---|---|
| 1 | 20 |
| 2 | 10 |
| 3 | 5 |
| 4 | 3 |
| 5 | 1 |

**Table 4.25 Site Character ($C_s$)**

| Site Characteristics | Parameter |
|---|---|
| a | 1 |
| b | 2 |
| c | 3 |
| d | 4 |
| | |

## *A.4.3 Joint Width*

The design section provides guidance on optimum joint widths for stone element paving. If the joint is either narrower or wider than this optimum then the potential for failure of the joint is increased. The parameter values for joint width reflect this. The influence of this parameter is not great and the values are based on judgement at present in the absence of any quantified scientific relationships. The parameter values are shown in Table 4.26.

### *A.4.4 Bedding Thickness*

As with joint width the design provides guidance on optimum bedding thickness for stone element pavements. If the bed thickness is less or greater than this optimum then the potential for failure is increased. Of particular relevance in relation to bedding is variability. Limits for tolerances are specified in the design section and these should be followed. Departure from these tolerances is likely to be the function of poor workmanship rather than poor design or specification. Therefore, poor bedding variation is accounted for in the workmanship parameter. The parameter values are shown in Table 4.27.

**Table 4.26 Joint Width ($J_w$)**

| Joint Width (mm) | Parameter |
|---|---|
| < 5 | 3 |
| 5 – 10 | 1.5 |
| 10 – 15 | 1 |
| 15 – 20 | 1.5 |
| > 20 | 2 |

**Table 4.27 Bedding Thickness ($B_t$)**

| Bed Thickness (mm) | Parameter |
|---|---|
| < 20 | 4 |
| 20 – 30 | 2 |
| 30 – 50 | 1 |
| 50 – 70 | 2 |
| . 70 | 4 |

### *A.4.5 Support Layer*

The influence of the support layer of the stone element pavement is complex. The three main issues are as follows: -

a. Compatibility with upper pavement layers
b. Stiffness, strength and density

For all natural stone pavement types it is essential that the structural support layer is compatible with the upper pavement layers in terms of stiffness. The picture is complicated slightly by the stress distribution characteristics of the surfacing where deep elements with a large surface area or well-jointed deep elements are likely to cause wide load distribution resulting in lower deformation of the structural layer. However, in general a flexible structural layer should only be used with a flexible surfacing and a rigid support layer should only be used with a rigid surfacing. To adopt any other strategy is high risk. The risk model accounts for this with a simple “on – off” switch parameter. If the structural layer and upper layers are compatible then the parameter has a value of 1, if they are not it has a value of 4.

The issue of strength, stiffness and density is complicated. In an unbound system the structural layer may be a well-compacted granular material or a flexible bituminous material. In a bound system the structural layer may be a stiff bituminous material or a hydraulically bound material. The key indicators of performance for these three types of material are different. For granular materials the key indicator is air voids, for bituminous materials it is stiffness and for concrete it is strength. There are therefore three tables of parameter values that reflect these different influences on performance. The logic of the values attributable to these parameters is as follows.

The neutral value for the parameter values has been selected as the minimum requirement for the design. If the structural layer performs above this minimum there is little benefit to the pavement – i.e. the structural layer is over designed. If however the performance falls below the minimum then the effect on the pavement can be significant. Therefore there is a skewed distribution of values about the neutral value for these parameter sets. The values are shown in tables 4.28 and 4.29.

**Table 4.28 Flexible Construction: Support Layer Characteristics ($L_{sf}$)**

| | | | |
|---|---|---|---|
| Compatible | 1 | Incompatible | 4 |

| Granular | | | Bituminous | | | Cement Bound | |
|---|---|---|---|---|---|---|---|
| Compaction | Parameter | | Stiffness GPa | Parameter | | Strength $N/mm^2$ | Parameter |
| To Series 800 | 1 | | < 1 | 1.5 | | NA | 2 |
| Other spec. | 3 | | 1 – 2 | 1 | | | |
| Not spec. | 8 | | 2 – 3 | 0.9 | | | |
| | | | > 3 | 0.9 | | | |

**Table 4.29 Rigid Construction: Support Layer Characteristics ($L_{sr}$)**

| | | | |
|---|---|---|---|
| Compatible | 1 | Incompatible | 4 |

| Granular | | | Bituminous | | | Cement Bound | |
|---|---|---|---|---|---|---|---|
| Compaction | Parameter | | Stiffness GPa | Parameter | | Strength $N/mm^2$ | Parameter |
| To Series 800 | 1 | | < 2 | 2 | | < 20 | 2 |
| Other spec. | 5 | | 2 – 3 | 1.2 | | 20 – 30 | 1 |
| Not spec. | 15 | | 3 – 4 | 1 | | 30 – 40 | 0.9 |
| | | | 4 - 6 | 0.9 | | > 40 | 0.8 |
| | | | > 6 | 0.8 | | | |

### *A.4.6 Workmanship*

This is one of the greatest influences on the likely performance of a natural stone pavement and so many of the causes of failure can be attributed to poor workmanship. It is also one of the most difficult things to quantify in a scientific fashion. For the purposed of the risk model it is essential that the parameter values for workmanship reflect the potentially disastrous effect of poor workmanship. Three descriptive categories have been developed as follows: -

1. Poor. Defined as no specification of qualification and experience of operatives, no references from previous schemes, no experienced and skilled supervision.
2. Moderate. Defined as specification of qualification and experience of operatives, references from previous schemes, no experienced and skilled supervision, and no demonstration panel requirement.
3. Good. Defined as specified qualification and experience of operatives, named individual operatives required, references from previous schemes, experienced and skilled supervision, and demonstration panel.

The values are shown in Table 4.30

### *A.4.7 Stone Quality*

This has a relatively minor influence on the performance of natural stone paving and the parameter value range reflects this. If a stone quality selection process similar to that recommended by this guide is used then a parameter value of 1 is applied if it is not then a value of 1.1 is applied (Table 4.31).

**Table 4.30 Workmanship (W)**

| Specified Workmanship | Parameter |
|---|---|
| Poor | 10 |
| Moderate | 3 |
| Good | 1 |

**Table 4.31 Stone Quality (Q)**

| Stone Quality spec. | Parameter |
|---|---|
| Yes | 1 |
| No | 1.1 |
| | |

### *A.4.8 Calculation Procedure*

The calculation procedure for the Natural Stone Paving Failure Index ($FI_{nsp}$) is shown in Equation 4.4. It involves establishing which form of support mechanism, bedding or jointing, is appropriate to the type of elements being used and applying the appropriate equation from Section 1.2.1. This provides the starting value for the calculation of the Index. This value is then multiplied by the parameter values for each of the other parameters as shown in equation 4.4.

Equation 4.4 $FI_{nsp} = (R_j \text{ or } R_{ju} \text{ or } R_b) * T * C_s * (J_w \text{ or } B_t) * (L_{sf} \text{ or } L_{sr}) * W * Q$

A simple calculation template is included on the Calculation sheets below. There are three sheets one each for

- Flexible Construction
- Rigid Construction
- Flagstone and Tiles

To use the sheets insert the appropriate parameter values from the relevant tables and then follow the calculation procedure on the template.

## A.5 Use of the Natural Stone Paving Failure Index

The calculation process outlined above derives a value for the Index. If the value is above 10 then it is likely that at some point during its life the natural stone pavement in question will suffer failures. These failures are likely to be more than mere localised serviceability failures and are likely to require invasive repair rather than just surface maintenance. As the value increases above ten there is increasing risk of failure and increasing risk of that failure occurring early in the life of the pavement and / or being severe and widespread.

If the Index value is below ten then there is a low risk of significant failure occurring. There may be minor serviceability failures that can be remedied without significant invasive repair or localised failures that require minor invasive repair. The lower the value the less risk of either of these occurring.

It should be noted that in the case of unbound surfacings the model assumes that regular, appropriate maintenance of the surfacing is carried out. If this is not the case then a more severe failure than indicated by the index value could occur.

As indicated at the outset of this section the index is not intended as a definitive statement on the condition or likely performance of a pavement. It is intended to act a guide to those responsible for making decisions associated with the procurement and management of Natural Stone Streetscapes as to the risks that are associated with the various options that exist. In the case of existing schemes the Index could be used to evaluate the risks associated with the pavement during its functional life and the need to make provision for works at some future date.

## A.6 Calculation Sheets for Natural Stone Failure Index

### *A.6.1 Calculation Procedure 1 - Cubes, Setts and Blocks*

Step 1 - Enter Element type [ ]

If Sett, Cube or Block Continue on this Sheet. If Flagstone or Tile go to calculation procedure 3.

Step 2 - Enter Construction type [ ]

If Rigid continue on this sheet. If flexible go to calculation procedure 2.

Step 3 - Check element depth and look up parameter value from Table 4.12 or 4.13.

Enter depth parameter value **a** [ ]

Step 4 - Check element plan area and look up parameter value from Table 4.16 or 4.17.

Enter plan area parameter value **b** [ ]

Step 5 - Check joint strength and look up parameter value from Table 4.22.

Enter joint strength parameter value **c** [ ]

Step 6 - Check bedding strength and look up parameter value from Table 4.23.

Enter bedding strength parameter value **d** [ ]

Step 7 - Check element surface texture and look up parameter value from Table 4.21.

Enter surface texture parameter value **e** [ ]

Step 8 - Check laying pattern and look up parameter value from Table 4.20.

Enter laying pattern parameter value **f** [ ]

Step 9 - Calculate jointing controlled resistance parameter as follows**: -**

**(a [ ] X c [ ] x e [ ] x f [ ] ) + (0.1 x b [ ] X d [ ] x f [ ] )**

Step 10 - Enter jointing controlled resistance parameter $\mathbf{R_j}$ [ ]

Step 11 - Check traffic loading and look up parameter value from Table 4.24

Enter traffic loading parameter value **g** [ ]

Step 12 - Check site category and look up parameter value from Table 4.25

Enter site category parameter value **h** [ ]

## Calculation Procedure 1 - Cubes, Setts and Blocks (cont.)

Step 13 - Check joint width and look up parameter value from Table 4.26

Enter joint width parameter value **i** ☐

Step 14 - Check structural layer characteristics. Check Step 2 for construction type. If rigid look up structural layer parameter value from Table 4.29. If flexible look up value from Table 4.28.

Enter structural layer parameter value **j** ☐

Step 15 - Check workmanship and look up parameter value from Table 4.30

Enter workmanship parameter value **k** ☐

Step 16 - Check stone quality and look up parameter value from Table 4.31

Enter stone quality parameter value **l** ☐

Step 17 - Calculate Natural Stone Failure Index as Follows**: -**

**$R_j$** ☐ **x g** ☐ **x h** ☐ **x i** ☐ **x j** ☐ **x k** ☐ **x l** ☐

Enter the Natural Stone Paving Failure Index ☐

## *A.6.2 Calculation Procedure 2 - Cubes, Setts and Blocks - Flexible Construction*

Step 1 - Enter Element type [ ]

If Sett, Cube or Block Continue on this Sheet. If Flagstone or Tile go to calculation procedure 3.

Step 2 - Enter Construction type [ ]

If flexible continue on this sheet. If rigid go to calculation procedure 1.

Step 3 - Check element depth and look up parameter value from Table 4.12 or 4.13.

Enter depth parameter value **a** [ ]

Step 4 - Check element plan area and look up parameter value from Table 4.16 or 4.17.

Enter plan area parameter value **b** [ ]

Step 5 - Check joint strength and look up parameter value from Table 4.22.

Enter joint strength parameter value **c** [ ]

Step 6 - Check bedding strength and look up parameter value from Table 4.23.

Enter bedding strength parameter value **d** [ ]

Step 7 - Check element surface texture and look up parameter value from Table 4.21.

Enter surface texture parameter value **e** [ ]

Step 8 - Check laying pattern and look up parameter value from Table 4.20.

Enter laying pattern parameter value **f** [ ]

Step 9 - Calculate jointing controlled resistance parameter as follows**: -**

**(0.4 x a [ ] x c [ ] x e [ ] x f [ ]) + (0.6 x b [ ] x d [ ] x f [ ])**

Step 10 - Enter jointing controlled resistance parameter $\mathbf{R_{jf}}$ [ ]

Step 11 - Check traffic loading and look up parameter value from Table 4.24

Enter traffic loading parameter value **g** [ ]

Step 12 - Check site category and look up parameter value from Table 4.25

Enter site category parameter value **h** [ ]

## Calculation Procedure 2 - Cubes, Setts and Blocks - Flexible Construction (cont.)

Step 13 - Check joint width and look up parameter value from Table 4.26

Enter joint width parameter value
**i**

Step 14 - Check structural layer characteristics. Check Step 2 for construction type. If rigid look up structural layer parameter value from Table 4.29. If flexible look up value from Table 4.28.

Enter structural layer parameter value
**j**

Step 15 - Check workmanship and look up parameter value from Table 4.30

Enter workmanship parameter value
**k**

Step 16 - Check stone quality and look up parameter value from Table 4.31

Enter stone quality parameter value
**l**

Step 17 - Calculate Natural Stone Failure Index as Follows**: -**

**$R_{jf}$ ___ x g ___ x h ___ x i ___ x j ___ x k ___ x l ___**

Enter the Natural Stone Paving Failure Index

## *A.6.3 Calculation Procedure 3 - Flagstones and Tiles*

Step 1 - Enter Element type [ ]

If Flagstone or Tile continue on this Sheet. If Sett, Cube or Block go to calculation procedure 1.

Step 2 - Check element depth and look up parameter value from Table 4.14 or 4.15.

Enter depth parameter value **a** [ ]

Step 3 - Check element plan area and look up parameter value from Table 4.18 or 4.19.

Enter plan area parameter value **b** [ ]

Step 4 - Check joint strength and look up parameter value from Table 4.22.

Enter joint strength parameter value **c** [ ]

Step 5 - Check bedding strength and look up parameter value from Table 4.23.

Enter bedding strength parameter value **d** [ ]

Step 6 - Check element surface texture and look up parameter value from Table 4.21.

Enter surface texture parameter value **e** [ ]

Step 7 - Check laying pattern and look up parameter value from Table 4.20.

Enter plan area parameter value **f** [ ]

Step 8 - Calculate jointing controlled resistance parameter as follows**: -**

**(0.1 x a [ ] x c [ ] x e [ ] x f [ ]) + ( b [ ] x d [ ] x f [ ] )**

Step 9 - Enter jointing controlled resistance parameter **Rb** [ ]

Step 10 - Check traffic loading and look up parameter value from Table 4.24

Enter traffic loading parameter value **g** [ ]

Step 11 - Check site category and look up parameter value from Table 4.25

Enter site category parameter value **h** [ ]

## Calculation Procedure 3 - Flagstones and Tiles (cont.)

Step 12 - Check bedding depth and look up parameter value from table 4.27

Enter bedding depth parameter value
**i** ☐

Step 13 - Check construction type. Enter construction type ☐

Step 14 - Check structural layer characteristics. Check Step 13 for construction type. If rigid look up structural layer parameter value from Table 4.29. If flexible look up value from Table 4.28.

Enter structural layer parameter value
**j** ☐

Step 15 - Check workmanship and look up parameter value from Table 4.30

Enter workmanship parameter value
**k** ☐

Step 16 - Check stone quality and look up parameter value from Table 4.31

Enter stone quality parameter value
**l** ☐

Step 17 - Calculate Natural Stone Failure Index as Follows**: -**

$R_{jf}$ ☐ **x g** ☐ **x h** ☐ **x i** ☐ **x j** ☐ **x k** ☐ **x l** ☐

Enter the ☐