Anderton
CONCRETE PRODUCTS LTD

STEPOC DESIGN INFORMATION

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Stepoc is a system of highly engineered and dimensionally co-ordinated building modules that are designed to readily accept horizontal and vertical reinforcement for use where structural performance is the prime consideration.

Stepoc is traditionally used for cantilever retaining walls; however it can practically be used in any situation where reinforced concrete would normally be specified. Stepoc is a faster and more economic solution combining the ease of blockwork with the versatility of in-situ concrete.

The charts and information on the following pages are intended to display the range of strengths attainable when Stepoc walls are designed in accordance with BS EN 1996-1-1.

The document also includes an explanation of the derivation of the charts and is based on the tested Stepoc figures as given below:

Characteristic Compressive Strength (f_k)

Stepoc 200	14N/mm²
Stepoc 256	18N/mm²
Stepoc 325	18N/mm²

The charts are purely for indication purposes only and should not be used as part of the final structural design. A full design check should be carried out by a qualified engineer in accordance with the relevant design code.

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ANDERTON CONCRETE

STEPOC STRENGTH DERIVIATION TO BS EN 1996-1-1

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Introduction

The purpose of this document is to chart the theory behind the strength charts developed for the stepoc wall system.

Within these calculations the wall is considered to act as a reinforced masonry element with the fk of the masonry being gained from testing undertaken for the stepoc product. Therefore the following design standards have been adopted:

BS EN 1990
BS EN 1996-1-1

Analytical Development of Bending Capacity Curves

The calculations and derivations presented below develop and justify the ultimate moment capacity of the stepoc section as a function of the area of main bending reinforcement provided. They assume a rectangular compressive stress block in the system with linear strain throughout a plane of the section. Masonry within the tensile zone of the section is assumed cracked and therefore offers no bending resistance in the ultimate limit state condition.

The outcome of the calculations is a series of charts for each stepoc block unit that may be replicated in stepoc documents as initial design guidance.

```
(*Calculate the compressive stress block force*)
fd := fk/γMm;
Fc = b λ x fd; (*Adopt λ = 1*)
λ = 1;
Fc
```

$$\frac{b\,fk\,x}{\gamma Mm}$$

```
(*Calculate the tensile force in the reinforcement*)
Fs = As fyd;
fyd := fy/γMs;
Fs
```

$$\frac{As\,fy}{\gamma Ms}$$

```
(*Calculate the required depth of the stress block for internal
 equillibrium between the tensile and compressive forces within the section*)
xeq = x /. Solve[Fc == Fs, x][[1]]
```

$$\frac{As\,fy\,\gamma Mm}{b\,fk\,\gamma Ms}$$

```
(*Calculate the moment capacity of the section from a lever arm generated
 from the centre of the rectangular stress block to the centre of the steel*)
la := d - x/2 /. x → xeq;
MRdc = Fs la
```

$$\frac{As\,fy\left(d-\frac{As\,fy\,\gamma Mm}{2\,b\,fk\,\gamma Ms}\right)}{\gamma Ms}$$

```
(*Set this moment capacity equal to the ultimate limit state applied moment to
   provide the basic graphing equation. Set the material parameters for steel &
 the partial factors of safety on matial to provide a net equation for
 the are of steel required per metre of wall length. Equivalent
 of CAT I masonry unit assumed with high yield steel*)
```

$$\text{Muls} := \text{MRdc}\,10^{-6} \,/.\, \{b \to 1000,\ \gamma\text{Ms} \to 1.15,\ \gamma\text{Mm} \to 2,\ \text{fy} \to 500\}$$

Muls

$$0.000434783\,\text{As}\left(d - \frac{0.434783\,\text{As}}{\text{fk}}\right)$$

```
(*This equation for applied moment vs area of steel required is limited by a
 limit on the compressive stress block depth based on the following equation*)
```

$$\text{Mulslim} := 0.40 \times 1000\, d^2\, \text{fd}\, 10^{-6} \,/.\, \{\gamma\text{Mm} \to 2\}$$

```
(*Mplot is the ULS bending moment from the above two foundations ploted as
  a conditional statement. The graph below gives the ULS moment capacity of
  the stepoc section as a function of the area of steel provided in the wall -
 each of the stepc units is considered in turn*)
```

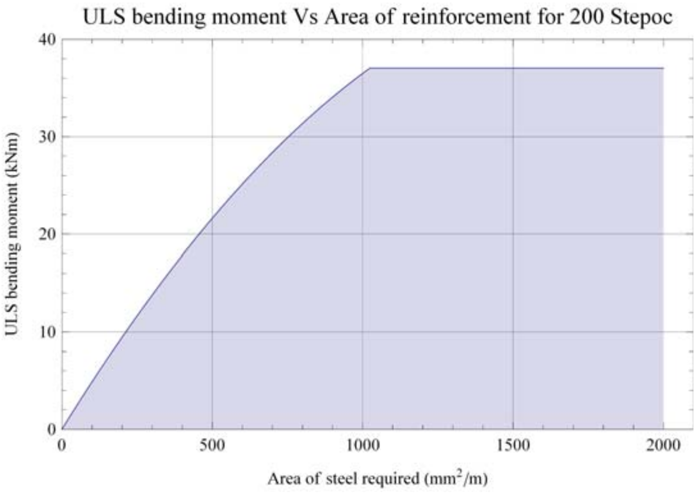
200mm Stepoc Unit

```
(*Calculations below are based on a 10mm longintudinal bar & 20mm vertical bar*)
```

$$d = 100 + \frac{\phi h}{2} + \frac{\phi v}{2} \,/.\, \{\phi h \to 10,\ \phi v \to 20\};$$

fk = 14;

Mplot := If[Muls < Mulslim, Muls, Mulslim]



256mm Stepoc Unit

```
(*Calculations below are based on a 10mm longintudinal bar & 20mm vertical bar*)
```

$$d = 151.5 + \frac{\phi h}{2} + \frac{\phi v}{2} \,/.\, \{\phi h \to 10,\ \phi v \to 20\};$$

fk = 18;

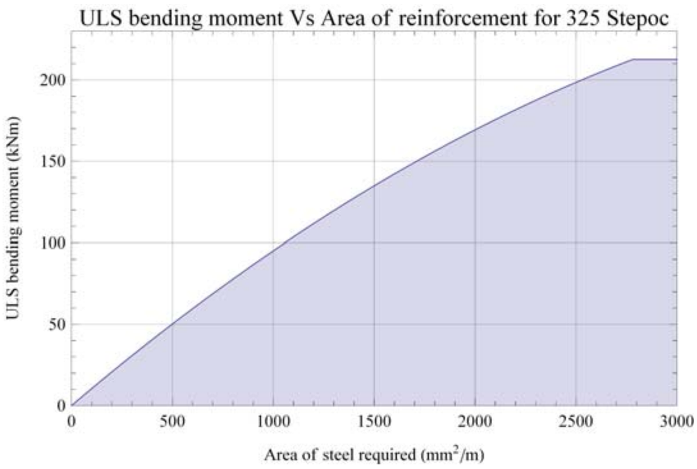
Mplot := If[Muls < Mulslim, Muls, Mulslim]

325mm Stepoc Unit

```
(*Calculations below are based on a 10mm longintudinal bar & 20mm vertical bar*)
```

$$d = 228 + \frac{\phi h}{2} + \frac{\phi v}{2} \ /. \ \{\phi h \to 10,\ \phi v \to 20\};$$

```
fk = 18;
Mplot := If[Muls < Mulslim, Muls, Mulslim]
```



Analytical Development of Shear Capacity Curves

The method of justification of shear capacity for the stepoc section is taken from BS EN 1996-1-1 Annex J

In[4]:=
$$Fvd := \frac{(0.35 + 17.5\,\rho)}{\gamma Mm}\, b\, d\, 10^{-3} \ /. \ \{b \to 1000,\ \gamma Mm \to 2\};$$

$$Fvmax := \frac{0.70}{\gamma Mm}\, b\, d\, 10^{-3} \ /. \ \{b \to 1000,\ \gamma Mm \to 2\};$$

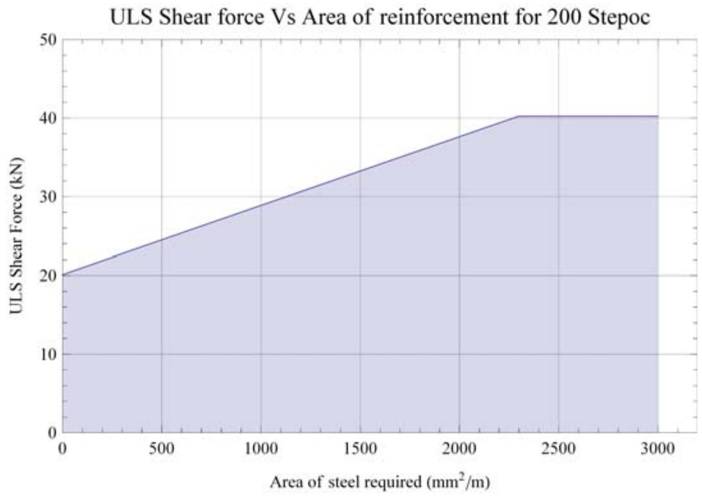
$$\rho := \frac{As}{b\, d} \ /. \ b \to 1000;$$

```
Vuls := If[Fvd < Fvmax, Fvd, Fvmax]
```

200mm Stepoc Unit

In[8]:= $d = 100 + \frac{\phi h}{2} + \frac{\phi v}{2}$ /. {$\phi h \to 10$, $\phi v \to 20$};

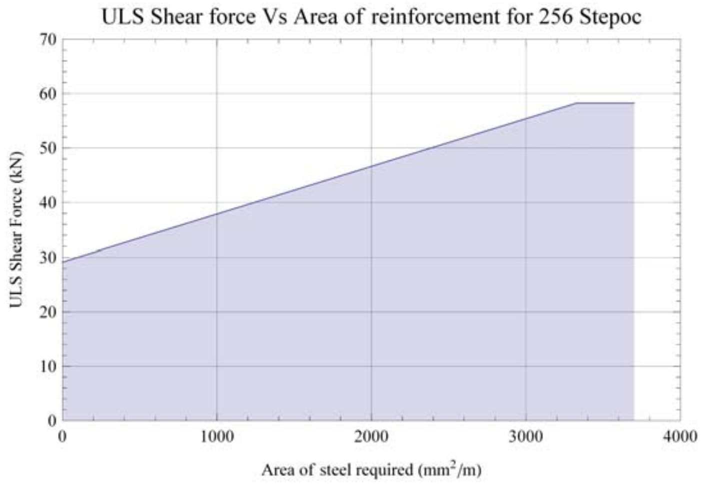
Out[9]=



256mm Stepoc Unit

In[10]:= $d = 151.5 + \frac{\phi h}{2} + \frac{\phi v}{2}$ /. {$\phi h \to 10$, $\phi v \to 20$};

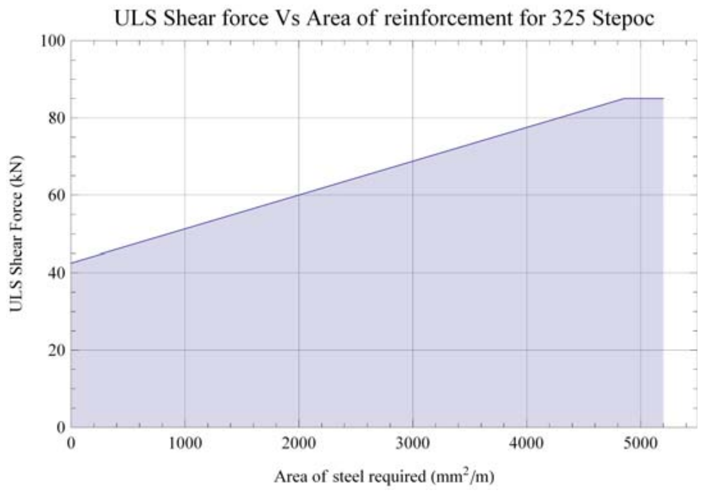
Out[16]=



325mm Stepoc Unit

In[18]:= $d = 228 + \frac{\phi h}{2} + \frac{\phi v}{2}$ /. {$\phi h \to 10$, $\phi v \to 20$};

Out[55]=



χ factors for retaining walls

Consider the Rankine distribution of soil pressure in a retaining wall system to calculate the shear span and the range of enhancement factors.

In[37]:=
```
pressure = ka (γ z γfe + q γfq); (*Limit State pressure distribution*)
shear = ∫pressure dz; (*Limit State shear force distribution*)
moment = ∫shear dz; (*Limit State moment distribution*)
av = moment/shear (*calculation of the shear span of a retaining wall*)
```

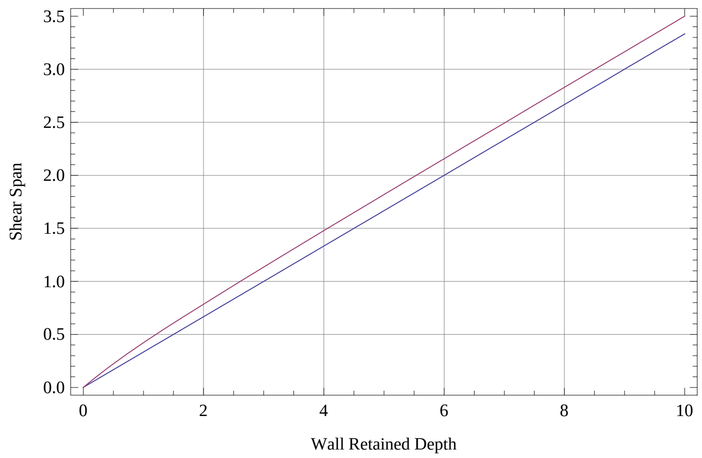
Out[37]=

$$\frac{\frac{1}{3} z^3 \gamma \gamma fe + q z^2 \gamma fq}{2 \left(\frac{1}{2} z^2 \gamma \gamma fe + q z \gamma fq\right)}$$

The above equation can be simplified by making sensible assumptions about the factors:

```
avlow = av /. {γ → 17, γfe → 1.35, γfq → 1.5, q → 0};
avhigh = av /. {γ → 20, γfe → 1.35, γfq → 1.5, q → 10};
```

Out[50]=



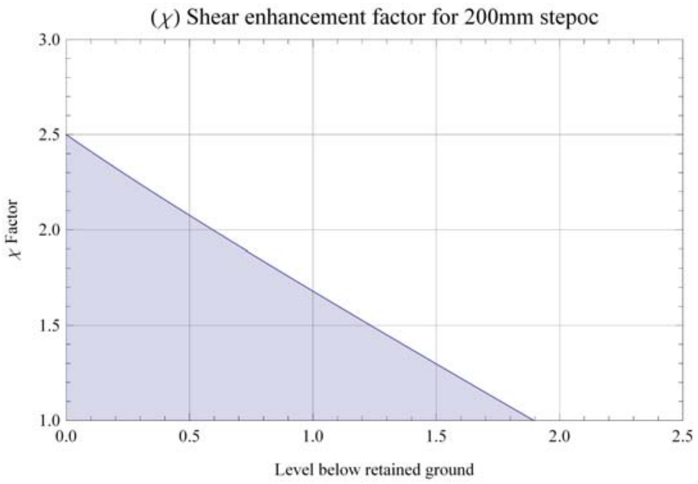
The above plot demonstrates that the variation is nominal between the two conditions chosen therefore an average of the two is taken in the shear capacity enhancement factor chart for stepoc retaining structures

```
avdesign = (avhigh + avlow)/2;
χ := 2.5 - 0.25 avdesign/(d 10^-3)
```

200mm stepoc unit

$$d = 100 + \frac{\phi h}{2} + \frac{\phi v}{2} \text{ /. } \{\phi h \to 10,\ \phi v \to 20\};$$

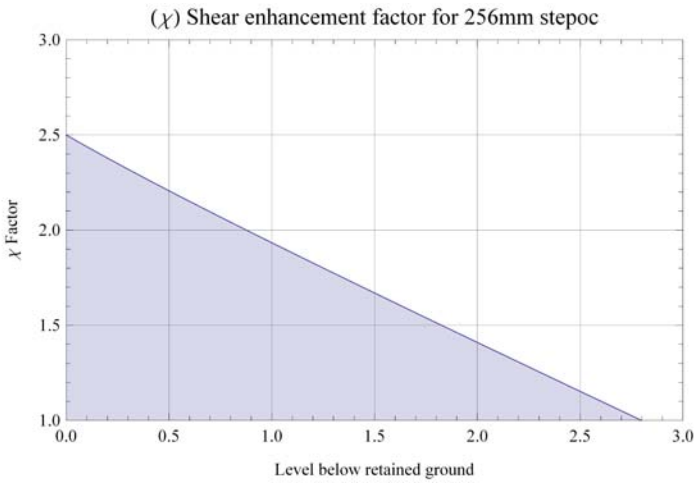
Out[73]=



256mm stepoc unit

$$d = 151.5 + \frac{\phi h}{2} + \frac{\phi v}{2} \text{ /. } \{\phi h \to 10,\ \phi v \to 20\};$$

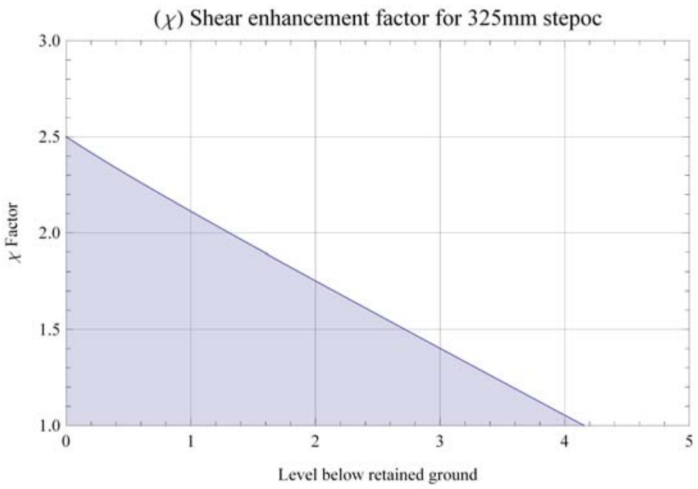
Out[75]=



325mm stepoc unit

$$d = 228 + \frac{\phi h}{2} + \frac{\phi v}{2} \text{ /. } \{\phi h \to 10,\ \phi v \to 20\};$$

Out[77]=



Use of the above charts

The intended use of the above charts is to follow the design process suggested below:

Establish the maximum ULS bending moment in the wall in accordance with BS EN 1990 & BS EN 1997-1-1 as applicable.

From the bending moment capacity curves read off the required area of reinforcement to satisfy the bending condition at ultimate limit state.

Establish the maximum ULS shear force in the wall.

From the shear capacity curves and the reinforcement required to resist bending establish the shear capacity of the section. If this is greater than the applied shear at ULS then the shear capacity of the wall is adequate.

If the element is a retaining wall, it may be possible to enhance the shear capacity of the wall by multiplication by the shear enhancement factor. For retaining walls read off the shear enhancement factor from the charts based on the depth of the applied shear below the retained surface and multiply this by the basic shear capacity for the section to gain the ULS shear capacity. If this is greater than the applied shear then the wall section is adequate in this condition.

The above procedure does not assess deformation in the wall. This may either be done by using the deemed to satisfy span to depth ratios from BS EN 1996-1-1 or by direct assessment of deformation using analysis techniques from a reinforced concrete analogy.

Additional comment on shear

In tall retaining walls shear can be the lead design action. At the base of the wall the starter bars are present and it is possible to account for the starter bar area in the shear calculation providing that the starter bar continues for a calculated anchorage length past the point required. This is analogous to the strut tie model used for shear calculations in reinforced concrete and effectively means that the area of the starter bars contribute fully at the base of the wall to zero at their termination. It is therefore sometimes possible to increase the shear capacity of the wall by extending the length and diameter of the starter bars.