**Arch Program**

**Input: Basic Parameters**

1. Choose code:

* 2013 MSJC
* 2012 IBC and 2012 IRC (2011 MSJC)
* 2009 IBC and 2009 IRC (2008 MSJC)

2. Choose mortar type:

* Type N masonry cement
* Type S masonry cement
* Type N mortar cement/PCL
* Type S mortar cement/PCL

3. We need to get the masonry prism compressive strength, f’m. Ideally, there would be two options. One is that the user could directly input this, with units of psi. For example, they could input 2000 psi, and be done with it. The other option, which is not necessary, but nice, would be to allow the user to input the compressive strength of the brick, fu. The compressive strength of the brick is often known from the manufacturer, and then you can just look up the value of f’m from a table in the code. The code table is based on the following equations:

Type N mortar (either masonry cement or mortar cement/PCL): f’m = 0.2439fu + 487.8

Type S mortar: f’m = 0.3057fu + 480.4

The default values of f’m should be based on a brick compressive strength of 3000 psi, or an f’m of 1220 psi for Type N mortar and 1400 psi for Type S mortar.

4. Weight of arch, rho. The default value would be 10 psf/inch thickness. Allow the user to override if they would like.

5. Height of the brick above the arch, h. The load would be calculated as follows:

 A. If the height is less than L/2, then the arch carries the full weight of the brick. The load from the brick would be [rho\*t\*h]/12 units of lb/in

 B. If the height is greater than L/2, then the arch only carries a triangular load, with the rest of the brick “arching” over the opening. The load from the brick would be [(1/3)\*rho\*t\*L]/12 units of lb/in

**Input: Arch Type**

There are four arch types: Minor segmental, Major Segmental, Semi-circular, and Jack. The Semi-Circular is a special case of the Segmental.

**Minor Segmental Arch: Input Parameters**

Superimposed loads (not including arch weight)

 uniform load, wa: lb/ft

Arch geometry

 length, L: inch

 rise of arch, f: inch

depth, d: inch

 thickness of the arch, t: inch

If the length of the arch, L, exceeds 6 ft, we need a warning that the program is only valid for minor segmental arches up to 6 ft in length. Check the arch as a major segmental arch.

If rise of the arch does exceeds 0.15 times the span (f/L > 0.15), we need a warning that the program is only valid for minor segmental arches with f/L ≤ 0.15. Check the arch as a major segmental arch.

**Minor Segmental: Calculations:**

1. Find the total distributed load:

2. Find Horizontal thrust, H, and vertical reaction, V:

3. Find the angle of reaction at the skewback:

 If θ exceeds 24°, then the arch is no good. We have sliding.

4. Find the compressive stress at the skewback.

 If the compressive stress exceeds (1/3)f’m, then the arch is no good.

**Minor Segmental Arch: output**

The primary output would just be whether the arch is good or not. Detailed output would be the angle of the reaction at the setback, the horizontal thrust, the normal force at the setback (Nskew), and fm.

**Major Segmental Arch: Input Parameters**

Superimposed loads (not including arch weight)

 uniform load, wa: lb/ft

 concentrated load: P, lb

Arch geometry

 length, L: inch

 rise of arch, f: inch

depth, d: inch

 thickness of the arch, t: inch

If the length of the arch, L, exceeds 20 ft, we need a warning that the program is only valid for major segmental arches up to 20 ft in length.

**Major Segmental: Calculations:**

1. Find the total distributed load:

tρ

2. We will have to do numerical integration, which requires dividing the arch into small segments. Due to symmetry, we can only analyze half the arch. Using symmetry is only true for the final loop. BIA analyzed the entire arch and used 96 segments. Thus, 48 segments seems appropriate. However, since computing resources are readily available, I will suggest using 96 segment for each half. Set n=96. Also, the nice thing about the program is that we can easily change n and see what happens.

3. First set initial values.

 Then run a loop for n times (i=1 to 2n). dx = (L/2)/n. For each n, find the following.

4. Calculate the following value.

5. Run another loop from i=1 to 2n

6. Calculate the following values.

7. And one more loop form 0=1 to n

For each value of i, we need to check stresses.

* if fme(i) < -f’m/3 then we have failed in compression (the sign convention is such that compression stresses are negative)
* if fmi(i) < -f’m/3 then we have failed in compression
* if fme(i) > Ft then we have failed in tension
* if fmi(i) > Ft then we have failed in tension
* if fv(i) <= 15, then OK. If fv(i) >15 but Qx(i)<=0.45\*abs(Nx(i)), then OK. Otherwise, failed in shear.

The value of Ft is determined based on the following table.

|  |  |  |
| --- | --- | --- |
|  | 2013 MSJC2012 IBC and 2012 IRC (2011 MSJC) | 2009 IBC and 2009 IRC (2008 MSJC) |
| Type N masonry cement | 20 | 15 |
| Type S masonry cement | 32 | 24 |
| Type N mortar cement/PCL | 40 | 30 |
| Type S mortar cement/PCL | 53 | 40 |

Note to self: Need to talk to Chip about these. TechNote also lists values for hollow units. If you build an arch with hollow units, though, you then need net area and net section modulus to find stresses.

**Major Segmental Arch: output**

The primary output would just be whether the arch is good or not. If the arch was not good, we should say why it was not good: compressive stress too high, tensile stress too high, or shear too high (could be several of these). Detailed output might be a table of x, Mx, Vx, Hx, Nx, Qx, fme, fmi, and fv.

**Circular Arch: Input Parameters**

Superimposed loads (not including arch weight)

 uniform load, wa: lb/ft

 concentrated load: P, lb

Arch geometry

 Actual length of arch, Lact: inch

depth, d: inch

 thickness of the arch, t: inch

**Circular Arch: Calculations**

Find an equivalent major segmental arch with parameters:

Now solve as a major segmental arch with f and L from above.

**Jack Arch: Input Parameters**

Superimposed loads (not including arch weight)

 uniform load, wa: lb/ft

 concentrated load: P, lb

 Check box if user would like program to calculate and include weight of brick above the arch.

Arch geometry

 length, L: inch

 depth, d: inch

 thickness of the arch, t: inch

If the length of the arch, L, exceeds 10 ft, we need a warning that the program is only valid for jack arches up to 10 ft in length.

**Jack Arch: Calculations:**

1. Find the total distributed load: w = [wa + rho\*(d/12)\*t]/12 units of lb/in

 If box checked to include weight above the arch, then add in [(1/3)\*rho\*t\*L]/12 units of lb/in

2. Find the angle of reaction at the skewback:

 Changed from 4 to 2 in the denominator

 If θ exceeds 24°, then the arch is no good. We have sliding. Need to check absolute value. Theta can be negative.

3. Find Horizontal thrust, H, and vertical reaction, V:

4. Find the compressive stress at the midspan and the skewback.

 Using what I think is correct:

 If either of the compressive stresses exceeds (1/3)f’m, then the arch is no good.

**Jack Arch: output**

The primary output would just be whether the arch is good or not. Detailed output would be the angle of the reaction at the setback, the horizontal thrust, the vertical reaction, and fm at the midspan and skewback.

Side note: I think the equation for fm at the skewback has a mistake in it. For now we will go with the equation given, and can easily correct if we need to.