

# AFEM: Axisymmetric Project

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## Chapter 1

# Introduction

## Chapter 2

# Analytical Formulation

## Chapter 3

# Computational Implementation

The axisymmetric elements we produced are fundamentally quite simple. They modify the basic quad element found in pyfem2. This

### 3.1 Full integration

```
1 from numpy import *
2 from .isop2_4 import CSDIsoParametricQuad4 as BaseElement
3 # -----
4 # ----- Axisymmetric Quad Element -----
5 # -----
6 class AxiSymmetricQuad4(BaseElement):
7     ndir = 3
8     nshr = 1
9     integration = 4
10    elefab = {'formulation': 1}
11    gaussw = ones(4)
12    gaussp = array([[ -1., -1.], [ 1., -1.], [-1., 1.], [ 1., 1.]]) / sqrt(3.)
13    @property
14    def formulation(self):
15        return self.axisymmetric
16    @formulation.setter
17    def formulation(self, arg):
18        assert arg in (0, 1, 2)
19        self.axisymmetric = arg
20    def bmatrix(self, dN, N, xi, *args):
21        rp = dot(N, self.xc[:,0])
22        B = zeros((4, 8))
23        B[0, 0::2] = B[3, 1::2] = dN[0, :]
24        B[1, 1::2] = B[3, 0::2] = dN[1, :]
25        B[2, 0::2] = N / rp
26        return B
```

### 3.2 Selective Reduced Integration

```
1 from numpy import *
2 from .isop2_4 import CSDIsoParametricQuad4 as BaseElement
3 # -----
4 # ----- Axisymmetric Selective Reduced Integration Element -----
5 # -----
6 class AxiSymmetricQuad4SelectiveReduced(BaseElement):
7     ndir = 3
8     nshr = 1
9     integration = 4
10    elefab = {'formulation': 1}
11    gaussw = ones(4)
12    gaussp = array([[ -1., -1.], [ 1., -1.], [-1., 1.], [ 1., 1.]]) / sqrt(3.)
```

```

13 selective_reduced = True
14 srip = array([[0.,0.]])
15 sriw = array([4.])
16 @property
17 def formulation(self):
18     return self.axisymmetric
19 @formulation.setter
20 def formulation(self, arg):
21     assert arg in (0, 1, 2)
22     self.axisymmetric = arg
23 def bmatrix(self, dN, N, xi, *args):
24     rp = dot(N, self.xc[:,0])
25     B = zeros((4, 8))
26     B[0, 0::2] = B[3, 1::2] = dN[0, :]
27     B[1, 1::2] = B[3, 0::2] = dN[1, :]
28     B[2, 0::2] = N / rp
29     return B

```

### 3.3 Reduced Integration with Hourglass Control

```

1 from numpy import *
2 from .isop2_4 import CSDIsoParametricQuad4 as BaseElement
3 # -----
4 # ----- Axisymmetric Reduced Integration With Hourglass Element -----
5 # -----
6 class AxiSymmetricQuad4Reduced(BaseElement):
7     ndir = 3
8     nshr = 1
9     integration = 1
10    elefab = {'formulation': 1}
11    gaussw = array([4.])
12    gaussp = array([[0.,0.]])
13    hourglass_control = True
14    #HOURLASS CONTROL PARAMETERS
15    hglassp = array([[0.,0.,]])
16    hglassv = array([[1., -1., 1., -1.]])
17    #REST
18    @property
19    def formulation(self):
20        return self.axisymmetric
21    @formulation.setter
22    def formulation(self, arg):
23        assert arg in (0, 1, 2)
24        self.axisymmetric = arg
25    def bmatrix(self, dN, N, xi, *args):
26        rp = dot(N, self.xc[:,0])
27        B = zeros((4, 8))
28        B[0, 0::2] = B[3, 1::2] = dN[0, :]
29        B[1, 1::2] = B[3, 0::2] = dN[1, :]
30        B[2, 0::2] = N / rp
31        return B

```

### 3.4 Implementation

The following listing is required for `_init_.py` in order for the elements above to be implemented into `pyfem2`.

```

1 __all__ = ['PlaneStrainTria3', 'PlaneStressTria3',
2            'PlaneStrainQuad4BBar', 'PlaneStrainQuad4', 'PlaneStrainQuad4Reduced',
3            'PlaneStrainQuad4SelectiveReduced', 'PlaneStressQuad4',
4            'AxiSymmetricQuad4', 'AxiSymmetricQuad4SelectiveReduced',
5            'AxiSymmetricQuad4Reduced',
6            'PlaneStressQuad4Incompat', 'PlaneStrainQuad8BBar',
7            'PlaneStrainQuad8', 'PlaneStrainQuad8Reduced', 'PlaneStressQuad8',
8            'CSDIsoParametricElement', 'IsoPElement']
9
10 from .isoplib import CSDIsoParametricElement
11 IsoPElement = CSDIsoParametricElement

```

```

12
13 from .CSDT3EF import PlaneStrainTria3
14 from .CSDT3SF import PlaneStressTria3
15
16 from .CSDQ4EB import PlaneStrainQuad4BBar
17 from .CSDQ4EF import PlaneStrainQuad4
18 from .CSDQ4ER import PlaneStrainQuad4Reduced
19 from .CSDQ4ES import PlaneStrainQuad4SelectiveReduced
20
21 from .CSDAX4F import AxiSymmetricQuad4
22 from .CSDAX4S import AxiSymmetricQuad4SelectiveReduced
23 from .CSDAX4R import AxiSymmetricQuad4Reduced
24
25 from .CSDQ4SF import PlaneStressQuad4
26 from .CSDQ4SI import PlaneStressQuad4Incompat
27
28 from .CSDQ8EB import PlaneStrainQuad8BBar
29 from .CSDQ8EF import PlaneStrainQuad8
30 from .CSDQ8ER import PlaneStrainQuad8Reduced
31
32 from .CSDQ8SF import PlaneStressQuad8

```

## Chapter 4

# Verification Problems

## Chapter 5

# Performance Evaluation