



# **Accounting for Bond-Slip Effect in LS-DYNA using Constrained Beam in Solid Formulation**

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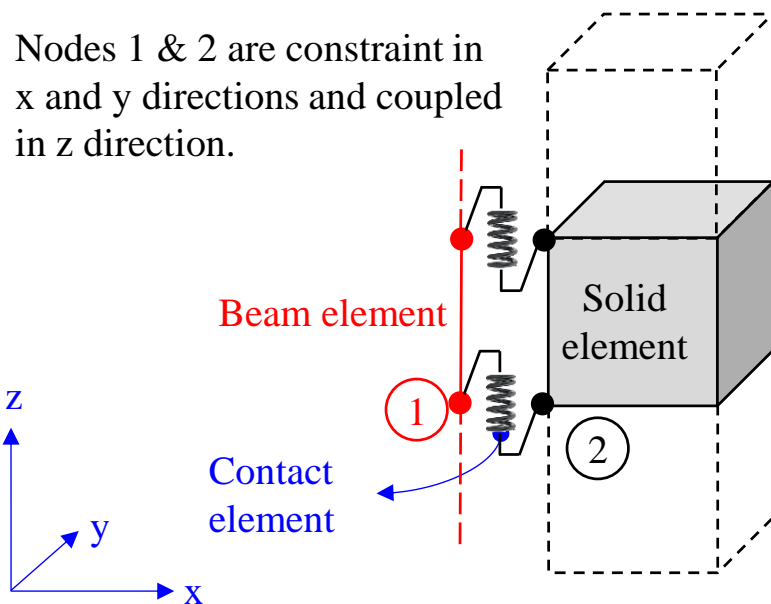
June 10, 2016

# Introduction

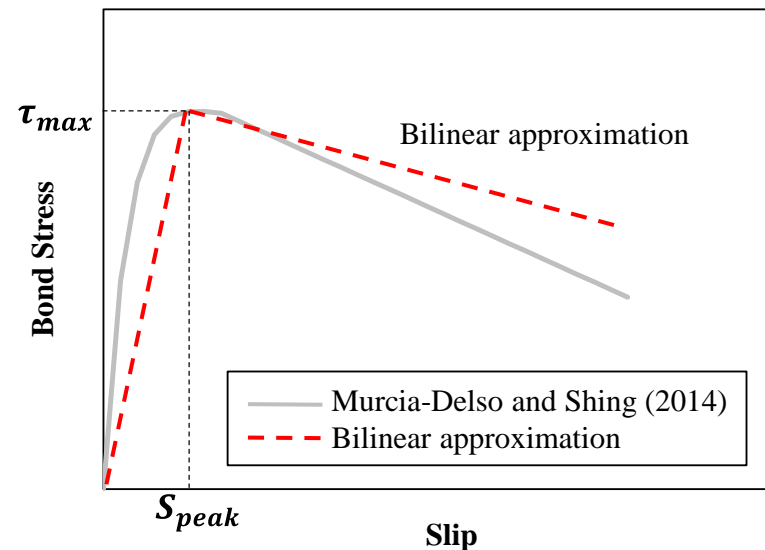
- Bond-slip effect must be accounted for in RC structures, particularly in several regions such as beam-to-column connections in RC frames.
- Inaccurate bond-slip models may lead to inaccurate damage patterns and load-displacement response in a simulation.

# Accounting for Bond-Slip Effect

- The most straightforward approach is to use the one-dimensional contact formulation:



## “Bond-slip law”



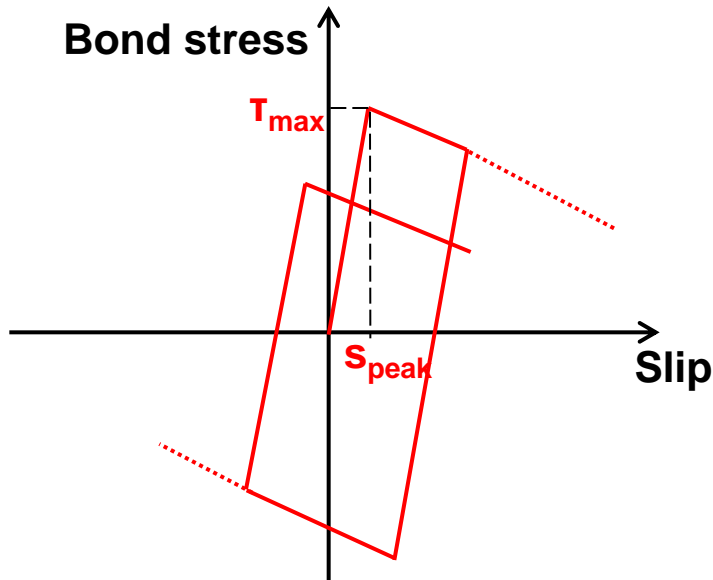
**This approach:**

**Does not capture the accurate bond-slip curve**  
**Cannot account for bond-slip cyclic deterioration**

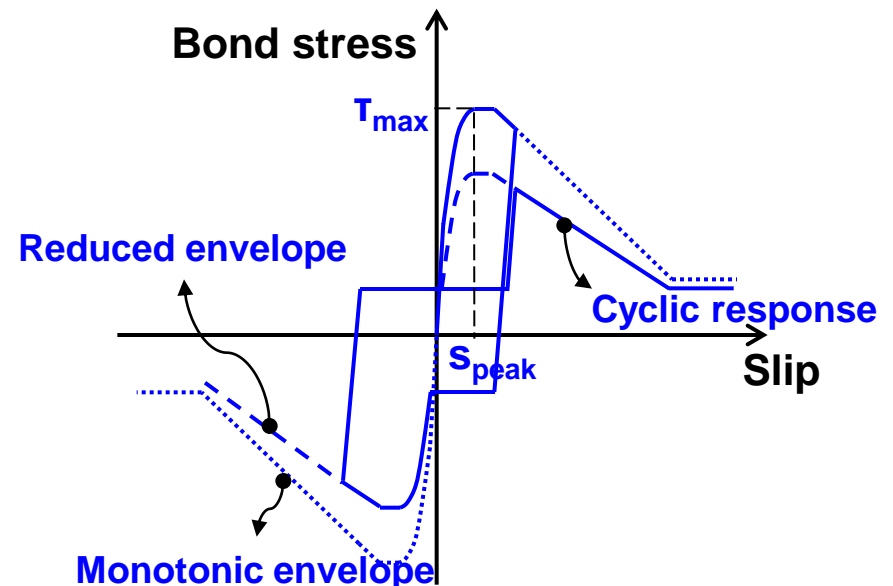
# Improved Formulation

- Using a modification of the formulation for constrained beam in solid (Chen 2016).
- Modification allows user-defined laws to accurately capture bond-slip effect.

Cyclic response for elastic-perfectly plastic material with damage used in 1D contact

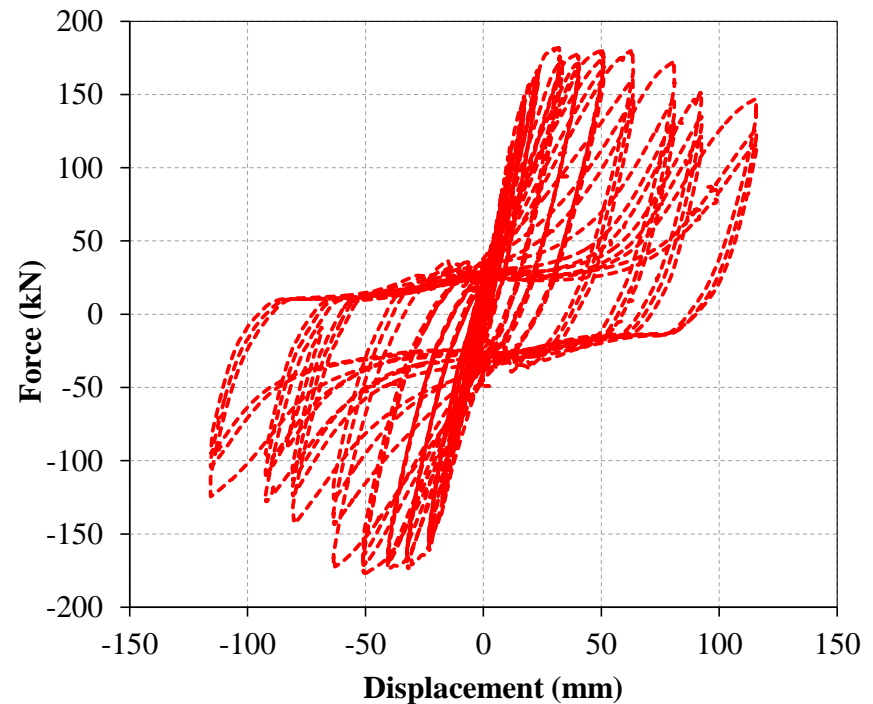
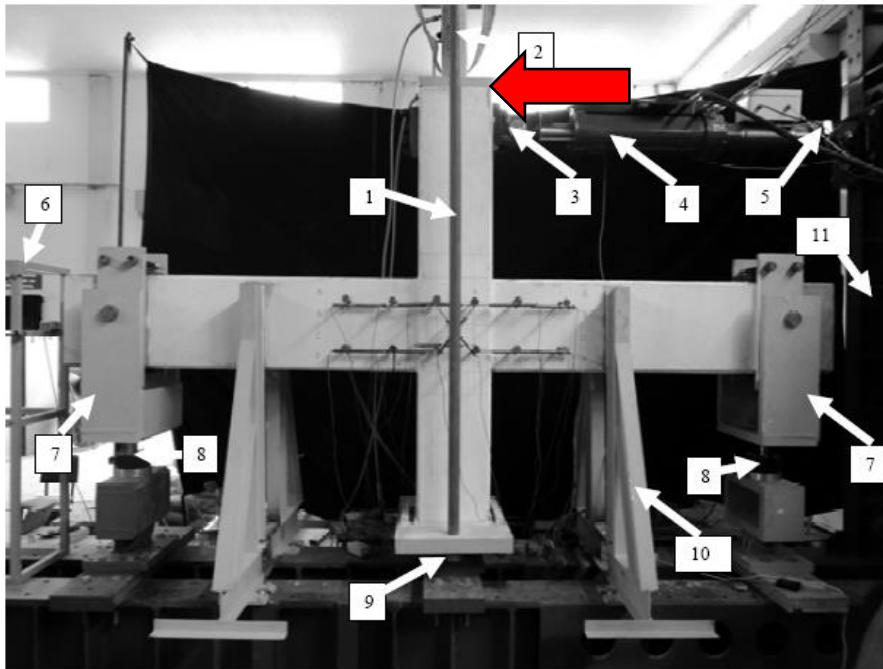


Bond-slip law by Murcia-Delso and Shing (2014) used in improved formulation



# Validation Analysis

- For a RC beam-to-column connection tested by Girgin et al. (2015).
- The obtained hysteretic response and damage pattern were significantly affected by rebar slip.



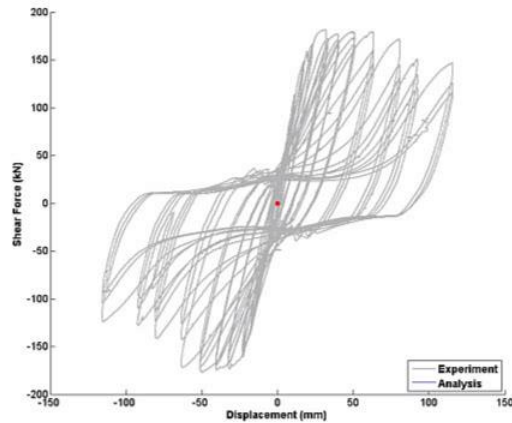
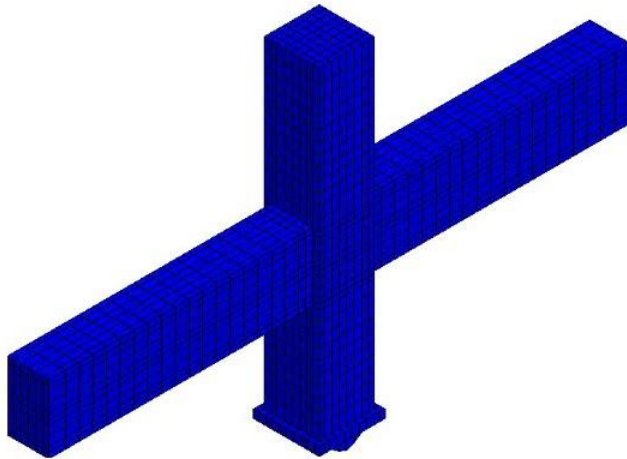
# Validation Analysis

LS-DYNA keyword deck by LS-PrePost

Time = 0  
Contours of History Variable#8  
min=0, at elem# 5  
max=1.27312e-05, at elem# 17317

Fringe Levels

1.500e-01  
1.350e-01  
1.200e-01  
1.050e-01  
9.000e-02  
7.500e-02  
6.000e-02  
4.500e-02  
3.000e-02  
1.500e-02  
0.000e+00

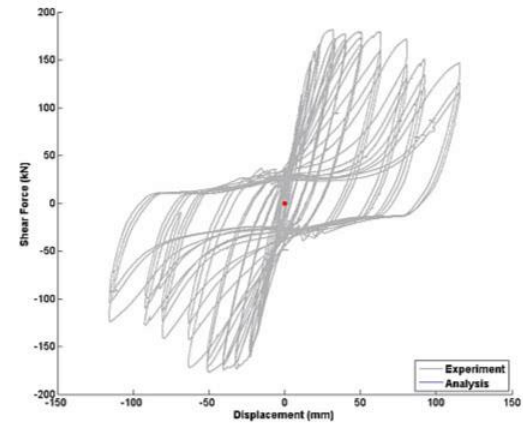
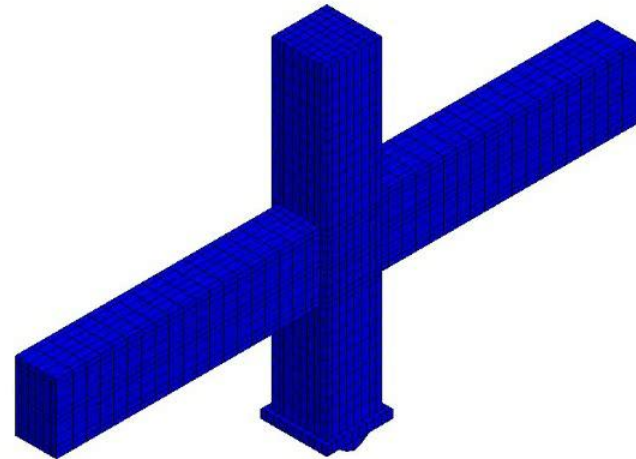


LS-DYNA keyword deck by LS-PrePost

Time = 0  
Contours of History Variable#8  
min=0, at elem# 5  
max=0, at elem# 5

Fringe Levels

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1.350e-01  
1.200e-01  
1.050e-01  
9.000e-02  
7.500e-02  
6.000e-02  
4.500e-02  
3.000e-02  
1.500e-02  
0.000e+00



# Validation Analysis

## With 1D Contact

LS-DYNA keyword deck by LS-PrePost

Time = 132.8

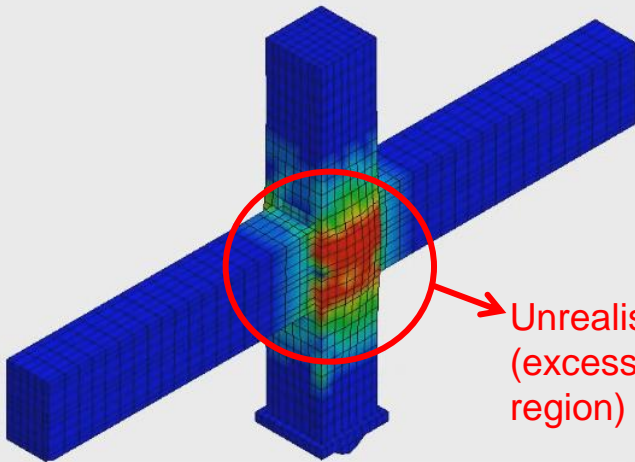
Contours of History Variable#8

min=-0.000206497, at elem# 5015

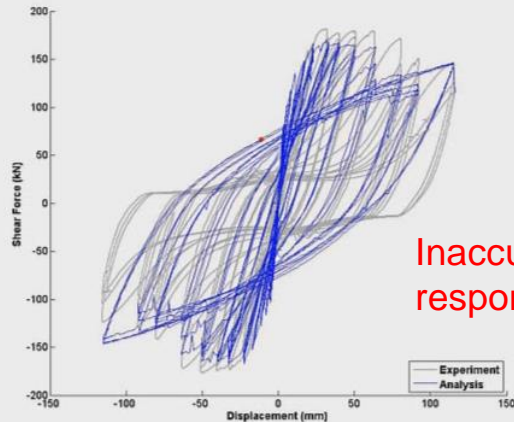
max=0.553537, at elem# 121

Fringe Levels

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1.050e-01  
9.000e-02  
7.500e-02  
6.000e-02  
4.500e-02  
3.000e-02  
1.500e-02  
0.000e+00



Unrealistic damage pattern  
(excessive damage in joint region)



Inaccurate hysteretic  
response

## With Improved Formulation

LS-DYNA keyword deck by LS-PrePost

Time = 132.8

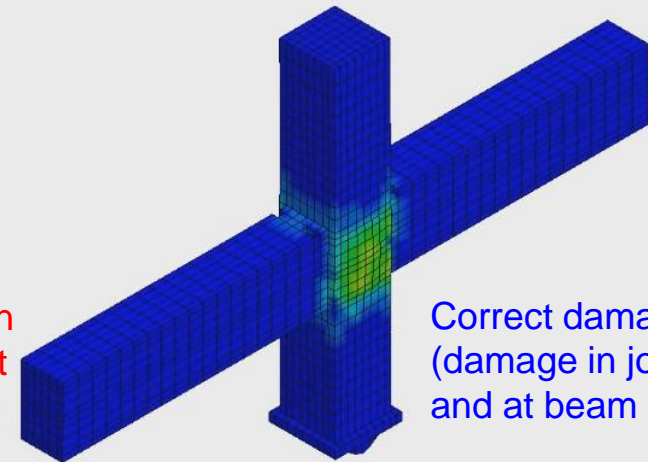
Contours of History Variable#8

min=-8.18324e-06, at elem# 14254

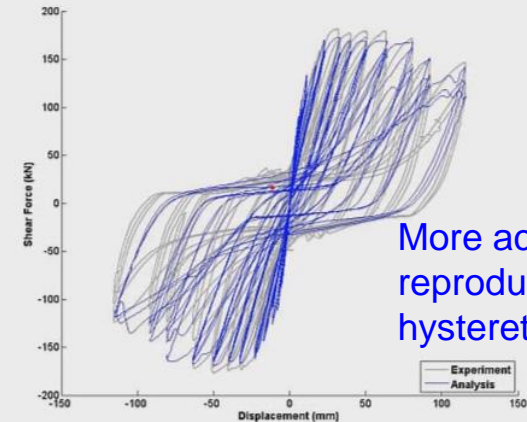
max=0.205773, at elem# 6006

Fringe Levels

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1.350e-01  
1.200e-01  
1.050e-01  
9.000e-02  
7.500e-02  
6.000e-02  
4.500e-02  
3.000e-02  
1.500e-02  
0.000e+00



Correct damage pattern  
(damage in joint region  
and at beam ends)



More accurate  
reproduction of  
hysteretic response