Analysis of different types of braces and chord connection in (CFST) k -joints under various boundary conditions

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Abstract - *Reusing structural elements is an effective way to prompt sustainable development with reduced energy consumption and gas emission. In current practice, steel members can be easily deconstructed and reused whilst the recycling of structural materials in steel-concrete composite construction has been found challenging. With the increasing material consumption in composite construction due to their well-recognized structural benefits, it is essential to explore the demountability of such structures. Limited previous research indicates that there is a lack of understanding or mature design specification for demountable composite connections. This paper thus presents an innovative design of demountable K-joints with concrete-filled steel tubular (CFST) chords and circular hollow section (CHS) braces connected using blind bolts. A detailed finite element analysis (FEA) modelling was established and validated against reported test data on bolted CFST connections. The model was then used to investigate the performance of different shapes of braces in k-joint. Also, it was analysed to find out which brace angle of the k joint gives the better performance and for parametric investigation using the length (gap) between the braces.*

***Key Words*: FEA, CFST, k joint, CHS, demountability, composite construction.**

1.INTRODUCTION

Total world crude steel production in 2017 was 1689 million tones, approximately 50% of which was attributed to buildings and infrastructure. To reduce the negative environmental effect, it is encouraged worldwide to reuse constructional materials. The idea of reusing structural steel has been adopted in practical designs such as the Sydney Olympic stadium and temporary carpark in UK. Generally, the key design of such demountable structures lies in their deconstructive connections, which are usually achieved by using demountable shear connectors or blind bolts.[3]

CFST (concrete-filled steel tubular) K-joint is joints with concrete-filled steel tubular (CFST) chords and hollow section braces connected using blind bolts. CFST K-joints formed by concrete filled chords and hollow section (CHS) braces are likely used in practice. The infilled chord concrete contributed to restraining the surface plasticity failure and enhanced the tensile performance for tubular connections and the overall structure. They are commonly used in large scale structures, e.g., long-span bridges and transmission towers, and temporary structures such as offshore platforms.[1]

A tubular joint is one of the efficient joint forms commonly used in steel tubular structures. It has the advantages of less steel consumption, good mechanical behaviour, clear path of force transmission and large bearing capacity. Hybrid tubular K-joints with circular braces and square chord meet the requirements of structural form and mechanical properties and are easy to design and construct, which are widely used in practical engineering. On the other hand, stainless steel structures have the advantages of good durability, easy processing, high-temperature resistance, excellent mechanical properties and beautiful appearance. They have been paid more and more attention in architectural and structural designs.

1.1 Objective

The main objectives of this study are:

- To investigate the performance of different shapes of braces in the K-joint.
- To examine which brace angle of the k joint gives the better performance.
- To study the performance of different gap distances between the braces in the K-joint.

1.2 Scope

The study focuses on the finite element analysis of k - joint using different position, angles, cross section of braces under nonlinear conditions. The study is only limited to k-joint used for structural steel hollow sections.

2. VALIDATION

In general, validation is the process of determining the extent to which the model represents the real-life situation. For validation the force verses displacement graph obtained from both experiment and numerical model from ANSYS is compared.

2.1 Geometry

The k joint consists of a chord having a span of 899mm and two circular braces of span 325mm each. The gap distance (g) of the gapped tubular K-joint was 72.6mm.

SPECIMEN: K-C-150 × 3-B-108 × 3

- Breadth of chord: 150.07 mm
- Thickness of chord: 2.94 mm
- Diameter of brace: 108.55 mm
- Thickness of brace :2.82mm

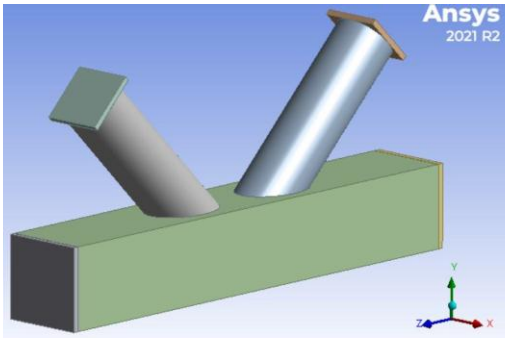

Fig -1: Geometry of k joint

2.2 Boundary Conditions

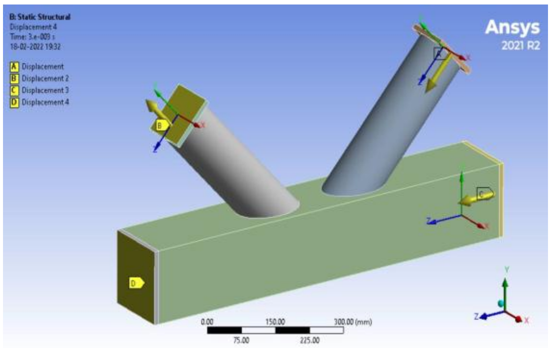

Fig -2: Boundary conditions

A = Brace subjected to compression
B = Brace subjected to tension
C = chord subjected to axial displacement
D = Fixed end

To stimulate the real conditions, k -joint is analysed with one side of square chord is fixed and load is applied as tension and compression on circular end plates and axial displacement on one side of square chord. The multilinear kinematic hardening rule was used for finite element analysis.

2.3 Validation Result

Validation is an important part of the thesis. The geometrical dimensions and material properties of k joint was adopted from the journal referred. Finite element modelling of k joint is validated by comparing the force displacement graph of numerical model with that of experimental study as shown in chart 1 and 2. Comparing Chat – 1 and Chart – 2 it can be seen that force displacement graph from validation obtained is similar to that in the journal.

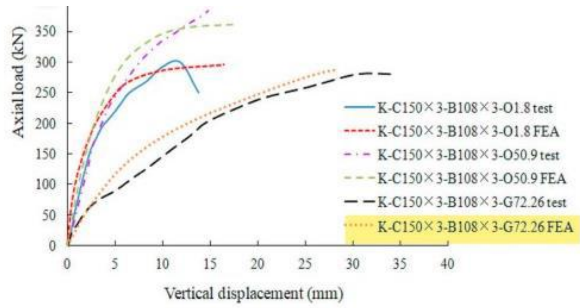

Chart -1: Force v/s displacement graph from paper [3]

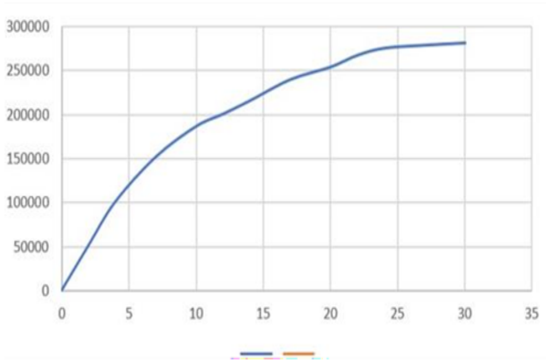

Chart -2: Force v/s displacement graph from validation

3. MODELLING AND ANALYSIS

The dimensions for all models were adopted from the journal and the boundary conditions was same for all models. For better understanding of the behavior of k – joints the Total deformation and equivalent stress distribution was also analysed for all the models.

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3.1 To investigate the performance of different shapes of braces in the K-joint

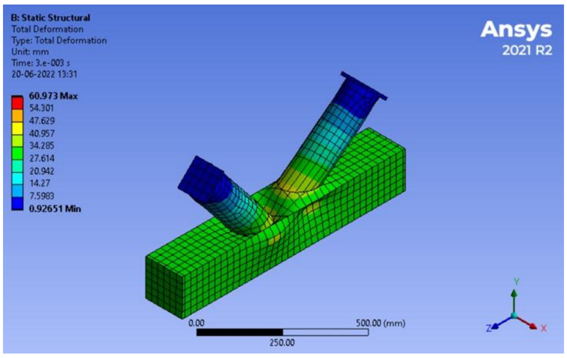

Fig -3: Total Deformation of k – joint with Circular braces

From the above figure it is observed that the maximum deformation of 60.973mm have been occurred at the bottom of brace. And the minimum deformation of 0.926mm have been occurred at the top of braces.

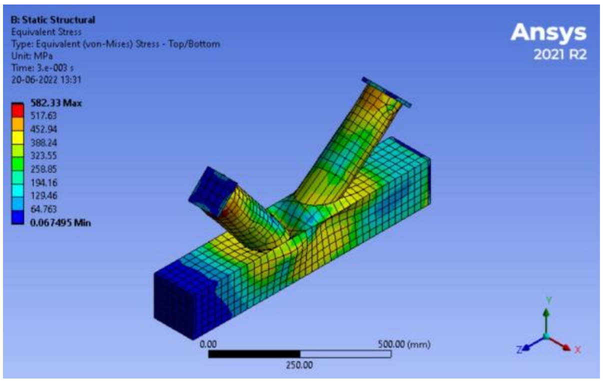

Fig -4: Equivalent stress distribution of k – joint with Circular braces

From the above figure it is observed that the maximum stress of 582.33MPa have been occurred at the bottom of braces and middle portion of the chords. And the minimum stress of 0.067MPa have been occurred at the top of braces and at the ends of chords.

Table – 1: Comparison of Total deformation and Equivalent stress distribution for different shapes of braces in k - joint

Cross - section of braces	Max value of Total Deformation in mm	Max value of Equivalent stress in Mpa
Circle	60.97	582.33
Rectangle	55.53	575.29
Hexagon	30.36	559.61
Pentagon	30.15	552.78

From the modelling and analysis of four different shapes of braces in the k – joint, Circular braces has the maximum stress of 582 kN and will undergo the maximum deformation of 60mm before failure.

3.2 To examine which brace angle of the k joint gives the better performance

In the previous section, we have modelled and analysed the k – joints with 90° brace angle for investigating the performance of different shapes of braces in the K-joint. Hence in this section we have analysed Circular, Rectangular and Pentagonal braced k – joints with brace angle 70° and 110°.

Table – 2: Comparison of Total deformation and Equivalent stress distribution for different brace angles in k – joint

Cross - section of braces	Max value of Total Deformation in mm			Max value of Equivalent stress in MPa		
	70°	90°	110°	70°	90°	110°
Circle	45	60	30	725	582	612
Rectangle	30	55	30	536	575	563
Pentagon	30	30	30	563	552	558

From the above table we can find that the k – joint with circular braces and having brace angle of 70° have the maximum value of equivalent stress than that of 110° and 90°.

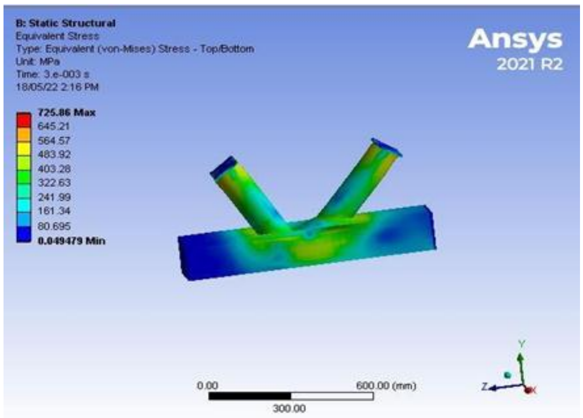

Fig -5: Equivalent Stress Distribution of k – joint with Circular braces and brace angle 70°

Similarly, the k – joint with rectangular braces and having brace angle of 90° have the maximum value of equivalent stress than that of 70°and 110°.

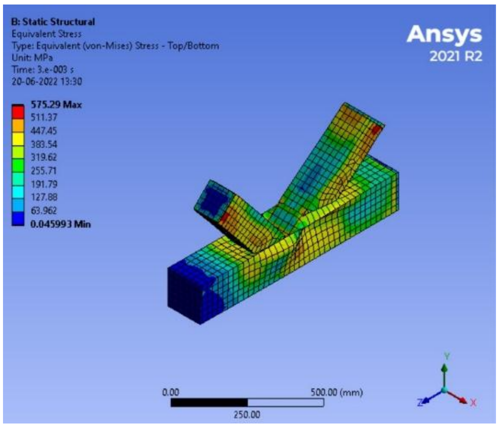

Fig -6: Equivalent Stress Distribution of k – joint with rectangular braces and brace angle 90°

And the k – joint with pentagonal braces and having brace angle of 70° have the maximum value of equivalent stress than that of 110° and 90°.

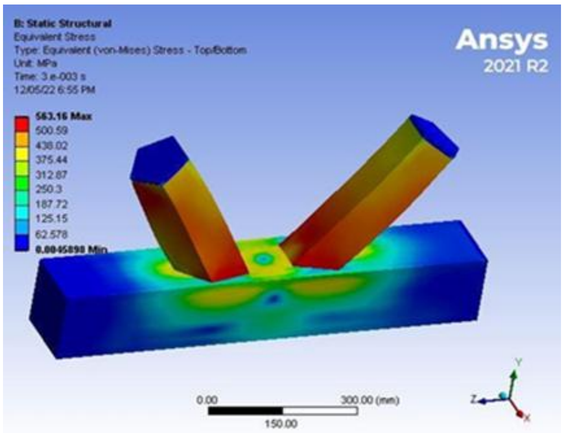

Fig -7: Equivalent Stress Distribution of k – joint with pentagonal braces and brace angle 70°

3.3 To study the performance of different gap distances between the braces in the K-joint

Table – 3: Comparison of Total deformation and Equivalent stress distribution for different brace gap distance between the k – joint

Cross - section of braces	Max value of Total Deformation in mm	Max value of Equivalent stress in Mpa
20mm	60.97	582.33
40mm	65.32	591.96
60mm	83.53	709.23

From the above table we can find that the k – joint with circular braces and gap distance of 60mm have the maximum value of equivalent stress.

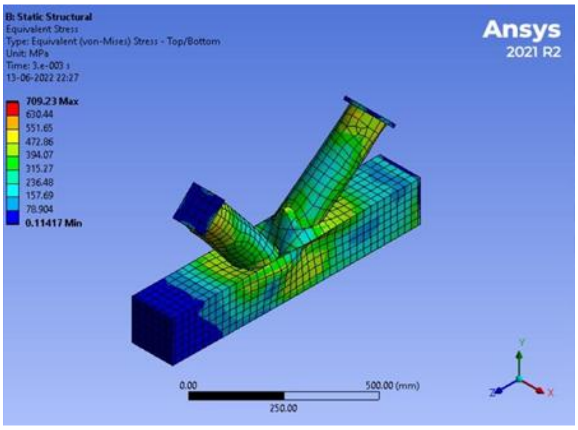

Fig -8: Equivalent Stress Distribution of k – joint with circular braces and gap distance 60mm

4.RESULT AND DISCUSSION

4.1 Performance of different shapes of braces in the K-joint

The force – displacement graphs of different shapes of braces in k – joint with brace angle 90° which was obtained from ANSYS is shown below.

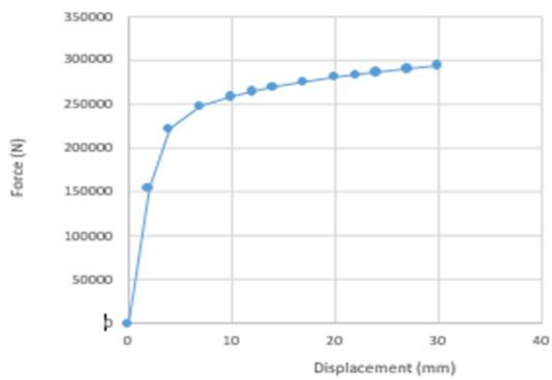

Chart -3: Performance of circular shaped braces in the k-joint

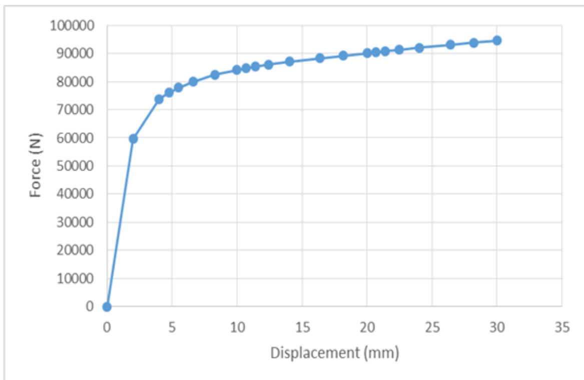

Chart -4: Performance of rectangular shaped braces in the k-joint

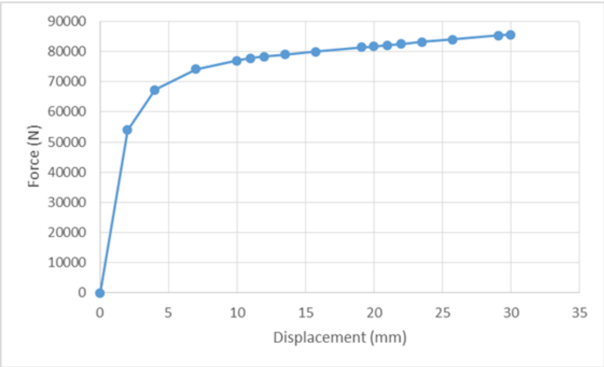

Chart -5: Performance of pentagonal shaped braces in the k-joint

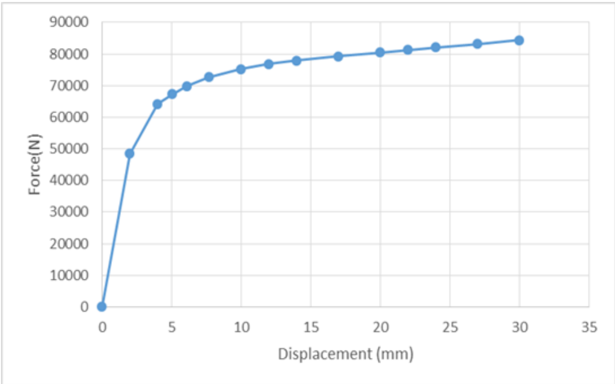

Chart -6: Performance of hexagonal shaped braces in the k-joint

The displacement applied and the corresponding forces obtained from ANSYS is summarized in the table below.

Table – 4: Comparison of shapes of braces in the k-joint

Shape of Braces	Displacement (mm)	Force (KN)
Circular	30	295
Rectangular	30	94.636
Pentagon	30	85.628
Hexagon	30	84.335

From the table 4, it is clear that the best shape is choose to be circular. It holds maximum force value of 295 kN which is comparatively much higher than others.

4.2 Performance of different brace angles in the K-joint

For 30mm displacement applied the corresponding maximum forces obtained for brace angles :90°,70° and 110° in the k -joint for circular, pentagonal and rectangular shaped braces with square chords are summarized below.

Table – 5: Comparison of max forces for different brace angles in k - joint

Cross - section of braces	Max force value from force - displacement graph in kN		
	70°	90°	110°
Circle	8.420	259	18.75
Rectangle	86.4	94.636	884
Pentagon	69.9	88.99	100

The force – displacement graphs of k – joints which can carry maximum forces are illustrated below.

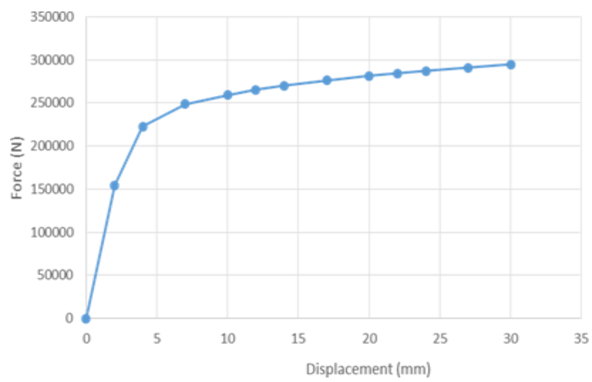

Chart -7: Performance of circular shaped braces in the k-joint with brace angle 90°

It can be concluded from the above data that k – joint with Circular shaped braces with brace angle 90° can carry max force of 259kN than other brace angles.

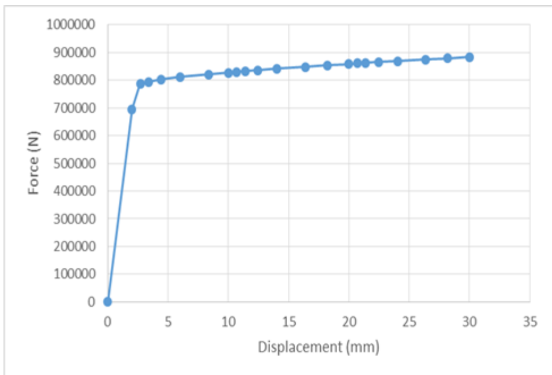

Chart -8: Performance of rectangular shaped braces in the k-joint with brace angle 110°

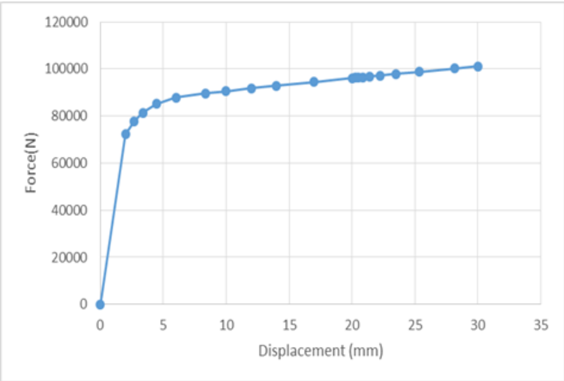

Chart -9: Performance of pentagonal shaped braces in the k-joint with brace angle 110°

Also, k – joint with Rectangular and Pentagonal shaped braces with brace angle 110° can carry max forces than 70° and 90°.

4.3 Performance of different gap distances between the K-joint

The force - displacement graphs obtained from ANSYS for k – joints with circular shaped braces and gap distances of 20mm, 40mm and 60mm is illustrated below.

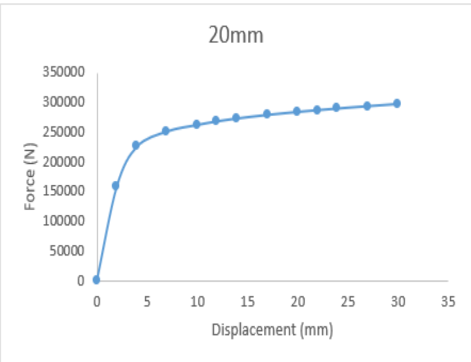

Chart -10: Performance of circular shaped braces in the k-joint with gap distance 20mm

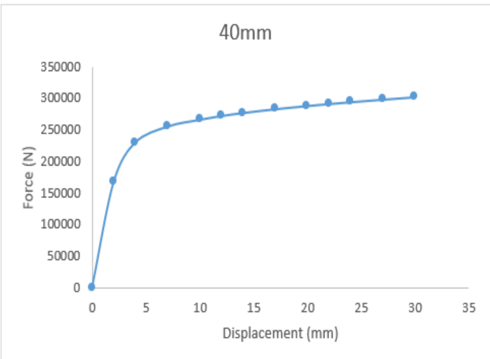

Chart -11: Performance of circular shaped braces in the k-joint with gap distance 40mm

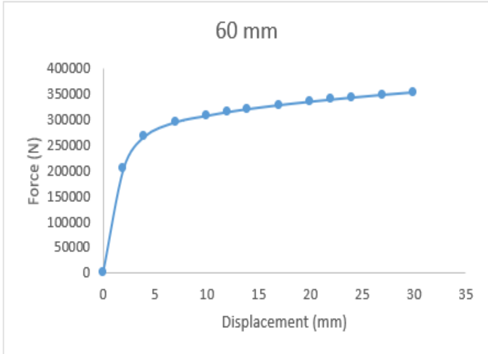

Chart -12: Performance of circular shaped braces in the k-joint with gap distance 60mm

The displacement applied and the corresponding maximum forces obtained for different gap distances in the k -joint for circular shaped braces with square chords are summarized in the table below.

Table – 6: Comparison of max forces for different gap distances in k - joint

Gap Distance (mm)	Displacement (mm)	Force (kN)
20	30	287
40	30	293
60	30	349

From the above table it is clear that k – joint with Circular shaped braces with 60mm gap distance can carry the max force of 349kN.

5. CONCLUSIONS

- The load carrying capacity of K- joint with circular braces was higher, when compared with the other shapes of braces which can carry 295 kN at 30mm displacement.
- K-joint with hexagon braces has less load carrying capacity compared to other shapes of braces which can take 83.335 kN at 30mm displacement.
- K-joint with circular braces gives better performance at 90 ° brace angle. It can take 295 kN at 30mm displacement.
- K-joint with other shapes of braces (rectangle, pentagon, and hexagon) gives the better performance at 110 ° brace angle. In these cases, as the angle between braces increases, the load carrying capacity also increases.
- The load carrying capacity is higher in k – joint with gap distance 60 mm compared with 20mm and 40mm.

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