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# Evaluation of the Effect of Asphalt and Geotextile Interlayer on Unbonded Concrete Overlay

# 비접착식 콘크리트 덧씌우기 포장에서의 아스팔트와 Geotextile 중간층에 대한 영향 평가

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|---|---|---|
| Cho, Seong-Hwan | 조성환 | North Carolina State University · Graduate Research Assistant (E-mail : shcho1402@gmail.com) |
| Im, Jeong Hyuk | 임정혁 | Member · North Carolina State University · Postdoctoral Research Associate · Ph.D. · Corresponding Author (E-mail : jhim5572@gmail.com) |
| Hwang, Sung-Do | 황성도 | Member · Korea Institute of Construction Technology · Research Fellow · Ph.D. (E-mail : sdhwang@kict.re.kr) |

## ABSTRACT

**PURPOSES :** The objective of this study is to investigate the effect of asphalt and geotextile interlayer on the fracture behavior of unbonded concrete overlay through a laboratory composite beam test.

**METHODS :** In order to evaluate the effect of interlayer materials on the fracture behavior of unbonded concrete overlay, a laboratory test of composite beam was conducted with different types of interlayer. The test results of the composite beam using two types of geotextile interlayer with different thicknesses were compared to the test results of the composite beam using the tradition type of asphalt interlayer. The unbonded concrete overlay on the existing concrete pavement without interlayer was set for the control condition.

**RESULTS AND CONCLUSION :** Overall, the laboratory composite beam test results did show the effect of asphalt and geotextile interlayer on the fracture behavior of composite concrete beams. The three-layer geotextile interlayer and HMA layer both increase the peak load when the first macrocrack occurs in the top concrete beam, while the HMA interlayer causes the smallest load drop percentage after the first macrocrack. The three-layer geotextile did show better performance than the single-layer geotextile through the greater peak load and smaller load drop percentage. It indicates that the thickness of geotextile interlayer will affect the fracture behavior of unbonded concrete overlay and the thicker geotextile interlayer is recommended.

**Keywords**
*asphalt and geotextile interlayer, unbonded concrete overlay, fracture behavior*

Corresponding Author : Im, Jeong Hyuk, Ph.D. Postdoctoral Research Associate, North Carolina State University, Department of Civil, Construction, and Environmental Engineering, Campus Box 7908, Mann Hall, 2501 Stinson Dr. Raleigh, NC 27695, USA
Tel : +1.919.996.9669 Fax : +1.919.515.7908
Email : jhim5572@gmail.com

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## 1. INTRODUCTION

An unbonded concrete overlay (UBCO) is a new concrete pavement over existing concrete pavement with an interlayer between them to break the bond. The major advantage of unbonded overlay is that it does not require much pre-overlay repair and can be applied to deteriorated pavements. The unbonded overlay is usually expected to be a long-lasting rehabilitation and perform over 20 years with adequate separation interlayer (Heckel, 2002). Unbonded concrete overlays are most cost-effective when the existing concrete pavement is badly deteriorated. Because two concrete layers are independent, unbonded concrete overlays perform structurally as if built on a strong, non-erodible base course. Thus they provide a more cost-effective option for deteriorated concrete pavements than rubblization and an asphalt overlay (C. Design, 1998).

Unbonded concrete overlays usually use an asphalt interlayer between the new and existing concrete pavement. The asphalt interlayer acts as a cushioning or separation layer and can prevent distresses from the underlying pavement reflecting into the overlay. For this reason, the term “unbonded” is used, although the interlayer usually adheres to the underlying pavement and concrete overlay.

The first use of geotextile as interlayer came from Germany for the purpose of preventing cracking failure due to a loss of base support. The cemented base was partially pulverized due to hydraulic pressures by water at the interface between the base and surface, which further led to the loss of base support. Based on the success of the placement of geotextile as the interlayer between concrete pavement and base, additional trials of this technique were conducted and the usage of the geotextile interlayer was standardized in Germany in 2001 (Rasmussen, 2009).

The objective of this study is to investigate the effect of asphalt and geotextile interlayer on the fracture behavior of unbonded concrete overlay through a laboratory composite beam test. The test results of the composite beam using two types of geotextile interlayer with different thicknesses were compared to the test results of the composite beam using the tradition type of asphalt interlayer. The unbonded concrete overlay on the existing concrete pavement without interlayer was set for the control condition.

## 2. OBJECTIVE

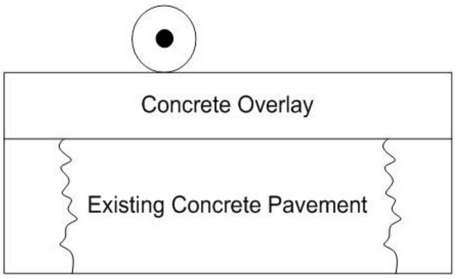
The objective of this study is to investigate the effect of asphalt and geotextile interlayer on the fracture behavior of unbonded concrete overlay through a laboratory composite beam test. The test results of the composite beam using two types of geotextile interlayer with different thicknesses were compared to the test results of the composite beam using the tradition type of asphalt interlayer. The unbonded concrete overlay on the existing concrete pavement without interlayer was set for the control condition.

## 3. BACKGROUND

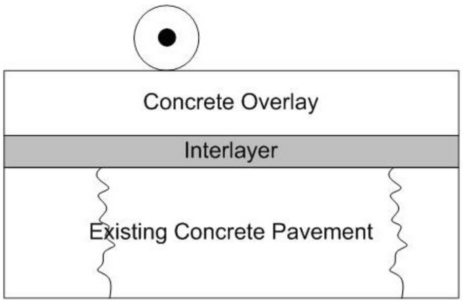
### 3.1. Bonded and Unbonded Concrete Overlay

Usually there are two rehabilitation options available when using concrete overlay: bonded and unbonded. Bonded concrete overlays (BCO) consist of a relatively thin concrete layer bonded to the top of the existing concrete pavement to increase its structural capacity.

Good candidates for bonded overlays are pavements which have little deterioration, but are too thin due to increased traffic volumes. Bonded concrete overlays are generally used when the existing concrete pavement is in relatively good condition and requires little pre-overlay repair. It is not recommended to use bonded concrete overlay when the amount of deteriorated slab cracking and joint spalling is substantial enough to require removal and replacement of the existing surface or when significant deterioration of the concrete slab has occurred due to durability problems (C. Design, 1998).



(a) Bonded Concrete Overlay



(b) Unbonded Concrete Overlay

Fig. 1 Bonded and Unbonded Concrete Overlay

While the existing concrete pavement should be in good condition for bonded concrete overlay (BCO), unbonded concrete overlay (UBCO) with an interlayer can be successfully used over the existing pavement in a poor condition (see Fig. 1). An unbonded concrete overlay is a good alternative for structural rehabilitation of deteriorated concrete pavements, because it is effective in controlling reflective cracking due to existing joints or cracks in underlying concrete pavements. The major advantage of unbonded overlays is that they require little pre-overlay repair before construction because the existing concrete pavement takes the role of a stabilized base like cement treated base. However, severe distress such as punchout in Continuously Reinforced Concrete Pavement (CRCP) or failed patches and areas of pumping in Jointed Concrete Pavement (JCP) should be repaired before the concrete overlay construction (McGhee, 1994).

### 3.2. Interlayer in Unbonded Concrete Overlay

The proper bond of interlayer is the most critical factor to affect the performance of bonded concrete overlay because a strong interlayer bond and the resulting shear transfer are critical to the distribution of the stress throughout the pavement structure (Karshenas et al., 2014). In contrast, the thickness and quality of the interlayer is one of the most important factors for unbonded concrete overlay due to the issue of reflective cracking.

Reflect cracking is generally defined as the propagation of cracks from the existing joint or crack in the underlying pavement or base course into the new overlay caused by load-induced and/or temperature-induced stresses (Cleveland et al., 2002). The external wheel load induces high bending stress in the concrete overlay when the vehicle is approaching the joint. The discontinuity in the existing joint or crack could create a stress concentration and decrease the structure capacity of the overlay (De Bondt, 1998). The contraction of the concrete slab due to temperature variation and/or shrinkage causes additional tensile stresses in the concrete overlay to make crack propagate.

The asphalt interlayer has been found effective in delaying reflective cracking of hot-mix asphalt (HMA) overlay on existing deteriorated PCC pavement and protecting pavement structure from moisture damage (Makowski et al. 2005). When the asphalt mixture is used as interlayer in concrete overlay, it acts similarly as in the HMA overlay and allows the concrete layers to move independently. The asphalt interlayer usually has a significantly lower modulus than regular HMA. It could increase the deformability of interface and reduce curling and warping stresses in the overlaid slab. In addition, the asphalt interlayer provides some protection against distresses in the existing pavement affecting the overlaid concrete.

Geotextile is usually used as separator to prevent the migration of fines into base/subbase from subgrade or provide filtration and drainage in wet subgrade soils. Geotextile is also used as interlayer in HMA overlay on concrete pavement to enhance the resistance to reflect cracking either by stress-relief or energy absorption (Khodaii 2009). Germany’s pavement design catalog now requires the use of a geotextile in concrete pavement with cement-treated base. In the past, Germany’s standard design requires the bonded interface between concrete slab and base and the cement-treated base being notched at locations matching the joints in the concrete slab. The required concrete slab thickness for the new design with geotextile interlayer is 10.6 in (27cm) compared to 10.2 in (26cm) for the old design with a bonded base. The used geotextile in Germany is a 0.2 in (5mm) thick nonwoven polyethylene or polypropylene. The geotextile is attached to the cement-treated base before the concrete slab is placed, and care is taken to prevent construction traffic from damaging the geotextile (Hall et al. 2007).

### 3.3. Composite Beam Test

The concept of composite beam test was firstly used in the Pavement Design II project in 2006. Tursun (2006) tested concrete overlays on hot-mixed asphalt (HMA) with unbonded interface on rubber pad. He found that higher peak loads (by 1.5 to 1.65times) resulted when the HMA beams were un-notched, compared to the notched beams. Braham (2006) conducted a similar test but consisted of two concrete beams separated by one inch of HMA. The HMA was unbonded to the top concrete beam but partially bonded to the bottom concrete beam. He concluded that polymer-modified asphalt as an interlayer between the concrete beams did not show significant changes to the peak load, but did slightly increase the CMOD readings upon cracking. A new test setup concept was developed in 2008 which replaced the rubber pad with a clay soil box to test the mixture effect on the fracture behavior of concrete overlay on HMA (Roesler et al. 2008).

Zhang and Li (2002) conducted third point composite beam test with fiber-reinforced concrete overlay and plain concrete overlay to compare their performances under different conditions. The test found that the fiber increased the load carrying capacity of the concrete beam and could prolong the fatigue life of the structure under traffic loading. Deformability of the fiber-reinforced concrete was also significantly increased compared to plain concrete and this could eliminate reflective cracking. The influence of the interfacial characteristics between overlay and the existing concrete pavement was also analyzed and it was found that the smooth casting surface leads to larger deformation than that of rough casting surface.

## 4. LABORATORY TEST

In order to evaluate the effect of interlayer material on the fracture behavior of unbonded concrete overlay, a laboratory test of composite beam supported by a soil foundation was conducted with different types of interlayer. The geometry and set-up of the composite beam test was based on a similar test used in the IDOT whitetopping project (Roesler et al. 2008). The composite beam was comprised of a concrete beam cast directly onto the interlayer material (HMA or geotextile) and another notched concrete beam sitting on a clay soil foundation. The notch depth is 0.6 inch and the composite concrete beam was loaded above the notch to force a stress concentration in the concrete material.

### 4.1. Concrete Mix Design

The concrete mix design used in this study was a low cement mix with w/c ratio of 0.3352 (provided by Amanda Bordelon). Table 1 shows the composition of the concrete mix design. The concrete mix was cured for two weeks before used in the test.

Table 1. Concrete Mix Design

| Material | Quantity |
|---|---|
| Water | 179 lb/cy |
| Type I Cement | 534 lb/cy |
| Coarse aggregate | 1957 lb/cy |
| Fine aggregate | 1220 lb/cy |
| Water reducer (Daracem) | 32.01 Fl oz/cy |
| Daravair | 10.68 Fl oz/cy |

### 4.2. Interlayer System

Two interlayer systems were used in the test, including a nonwovern geotextile and a fine-aggregate, asphalt-rich, polymer-modified asphalt mix interlayer. Currently there is no broad application of geotextile in unbonded concrete overlay except the German experience. The geotextile used in this study is manufactured by Propex, Inc. at Missouri. The detailed test data of the property of the geotextile is not available in this study.

The asphalt interlayer used in the study is highly flexible, impermeable hot mix asphalt (HMA) using high content of elastic-polymer modified asphalt and fine aggregate (nominal maximum aggregate size 4.75mm). Thus, the asphalt interlayer has softer stiffness than the regular dense mix and greater fatigue life and fracture energy.

### 4.3. Specimen Preparation

The bottom double-sized concrete beams (2.5×6×21 in.) were cast using steel molds and then cut to the dimensions of 2.5×3×15 in. The bottom concrete beams were saw-cut with 0.6-inch notch depth to simulate the joint or crack at existing PCC pavement. The asphalt interlayer was compacted using roller compactor with 4% air void and then cut into the beam dimensions of 0.5×3×15 in. (see Fig. 2).

The top double-sized concrete beams (2.5×6×21 in.) were directly cast onto the geotextile or asphalt interlayer using the steel molds and then cut to the dimensions of 2.5 × 3×15 in. (see Fig. 3). The top concrete beam and interlayer were then placed on the pre-cast bottom concrete beam to form the whole composite beam used in the test. For the control case without interlayer, the top concrete beam was cast separately and then placed on the pre-cast bottom concrete beam.

The existing soil box with inner dimension of 12×8×20 in. was used as foundation in the test. There was a thin layer of sand over the clay layer in the box to maintain a level surface and to hold in moisture. The clay layer was re-saturated before test.

(a) Loosed Sample

(b) Compactor

Fig. 2 Preparation of Asphalt Interlayer

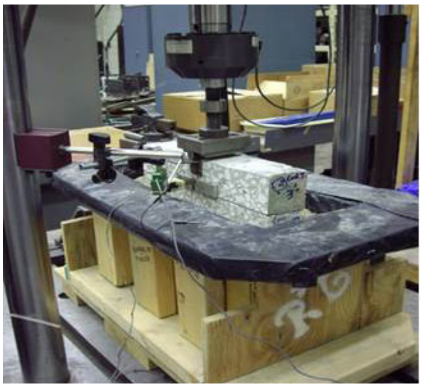
(a) Asphalt

(b) Geotextile

Fig. 3 Interlayer for Top Beam Cast

## 4.4. Test Setup and Instrumentation

The whole specimen was loaded with an 11-kips MTS servo-hydraulic actuator with the stroke position gauge being set at 0.02 in./min (0.5mm/min). An INSTRON 0.16 in. (4mm) range clip gauge was placed across the location over the notch to measure the crack opening that would initiate in the top concrete beam. The vertical dis-placement of the whole composite beam and soil was measured using a Linear Variable Differential Transducer (LVDT) with 1 in. (25mm) range. The test setup is illustrated in Fig. 4. Totally eight composite beams with two replicates for each interlay type



(a) Test Setup

(b) Instrumentation

Fig. 4 Composite Beam Test

Table 2. Summary of Test Cases with Different Interlayer Types

| Test case | Repli-cates | Interlayer type and thickness | Top beam thickness | Bottom beam thickness |
|---|---|---|---|---|
| Control | 2 | N/A | 2.5 | 2.5 |
| Geotextile 1 | 2 | Single-layer geotextile (0.16 in.) | 2.5 | 2.5 |
| Geotextile 3 | 2 | Three-layer geotextile (0.5 in.) | 2.5 | 2.5 |
| HMA | 2 | Asphalt mixture (0.5 in.) | 2.5* | 2.5 |

* Actual thickness is around 2.8 inch.

and control condition were tested in this study, as summarized in Table 2.

# 5. ANALYSIS OF TEST RESULTS

## 5.1. Load versus Deflection Curve

The load and the vertical deflection of the whole structure (beam and soil foundation) were plotted in Fig. 5. The load is the output from the load cell of MTS and the vertical deflection is measured from the LVDT. As the load increases before peak load, the deflection increases with the increase of load. After the load achieves the first peak load, the load drops due to the occurrence of macrocrack in the top beam. However, the load increases again because the beam can be supported by the soil foundation. It is noted that for the composite beam with HMA interlayer, there is no visible crack observed at the first peak load and the first macrocrack in the top beam occurs at the second peak load. The peak loads at which the first macrocrack in the top beam was observed were used in the analysis because the objective of this study is to compare the effect of interlayer types on the facture behavior of concrete overlay. It is noted that the second peak load was observed in the test when the macrocrack occurs in the bottom beam for the control case and the composite beam with geotextile interlayer.

Fig. 5 shows that the existence of interlayer increases the total beam deflection at peak load, especially for the case of three-layer geotextile. For the composite beam with geotextile interlayer, the increase of deflection does not indicate the increase of deform capacity of the concrete beam because the bulk material of geotextile was compressed first in the test which may cause the increase of total deflection.

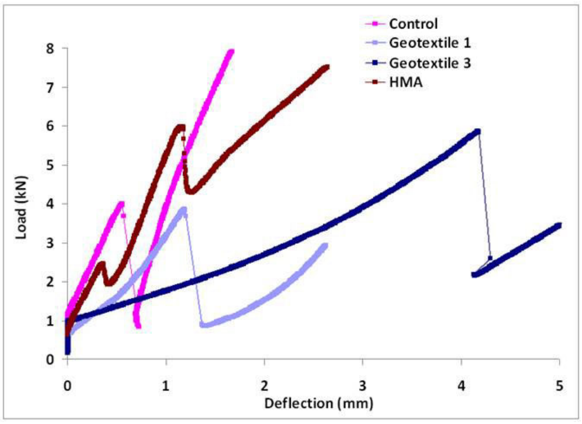


Fig. 5 Load versus Deflection Curves for Different Interlayer Types

## 5.2. Load versus Crack Opening Curve

The load and the crack opening of top concrete beam above notch were plotted in Fig. 6. As the load increases before peak load, the microcrack first develops in the top beam and the crack opening increases with the increase of load. As expected, the peak load from the crack opening curve was found the same as the peak load from the deflection curve. After the load achieves the peak load and a macrocrack occurs in the top beam, the load drops and the crack opening increases significantly even with the load drop. This indicates that the top concrete beam starts to lose its structure capacity.

Fig. 6 shows that the composite beams with HMA and three-layer geotextile interlayer have greater crack openings at peak load than the control case. In addition, the increase of crack opening during the load drop after peak load is less for the beam with HMA interlayer, compared to the control condition and the beam with geotextile interlayer. This is probably because the HMA interlayer is stiffer than the geotextile and it can contribute to the structure capacity.

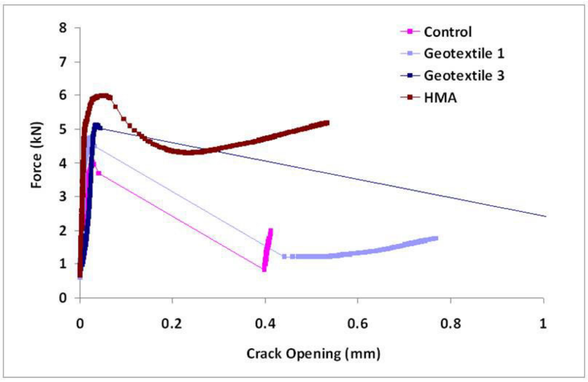
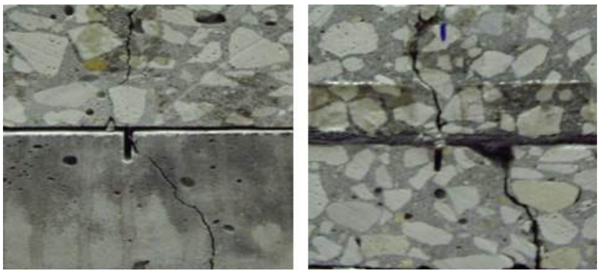


Fig. 6 Load versus Crack Opening Curves for Different Interlayer Types

## 5.3. Crack Development of Composite Beam

The crack development of composite beam after failure is shown in Fig. 7, respective for different interlayer types. These photographs were taken after the tests were halted when both top and bottom concrete beams were fractured and the soil foundation carried most of the load. It can be seen that generally the crack initiates from the notch and propagate upward and downward until going through the whole beam depth. The exact crack path could be dependent on the aggregate size and the distribution of internal air void in the concrete mixture. Both the straight-line and curved crack paths were observed in the test. The HMA and geotextile interlayers seemed to be well bonded with the top concrete beam during the test and after failure. No slippage failure was observed in the test.



Control　　Single-Layer Geotextile

Three-Layer Geotextile　　HMA

Fig. 7 Crack Development of Composite Beam after Full Failure

### 5.4. Comparison of Test Results

Fig. 8 and 9 compares the peak load and load drop percentage of the composite beam for different interlayer types. The peak load indicates the load capacity before a macrocrack occurs in the top beam above the notch and it can be associated with the performance of concrete overlay in field before crack happens. The load drop percentage was calculated as the difference between the peak load and minimum load (after drop) divided by the peak load. The load drop was thought as a factor to estimate the residual structure integrity of composite beam after a macrocrack has been formed. Previous researches have shown that the load carrying capacity of slabs was based on the residual strength of concrete beams (Roesler et al. 2004). Thus, the magnitude of the load drop percentage can be associated with the performance of concrete overlay in the field after initial cracking has occurred.

A relatively high variation was found for the peak load between two specimens. It is believed that the geometry of the specimen will affect the fracture behavior of the composite beam and this could be the main reason causing the high variation between two specimens for the same interlayer type. Generally, it was found that the three-layer geotextile interlayer and HMA layer increased the peak load when the first macrocrack occurred in the top concrete beam, while the HMA interlayer caused the smallest load drop percentage after the first macrocrack. This is probably because the HMA interlayer can still carry the load after the macrocrack occurs in the top concrete beam. The three-layer geotextile did show better performance than the single-layer geotextile through the greater peak load and smaller load drop percentage. It indicates that the thickness of geotextile interlayer will affect the fracture behavior of unbonded concrete overlay and the thicker geotextile interlayer is recommended.

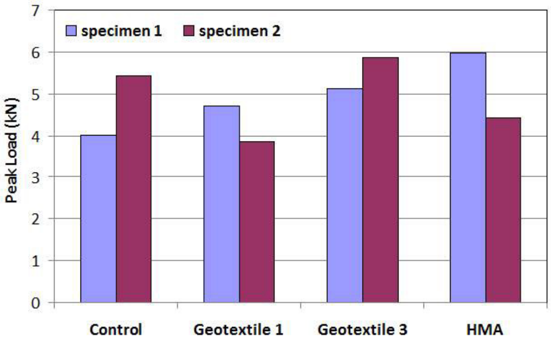


Fig. 8 Comparisons of Peak Loads for Different Interlayer Types

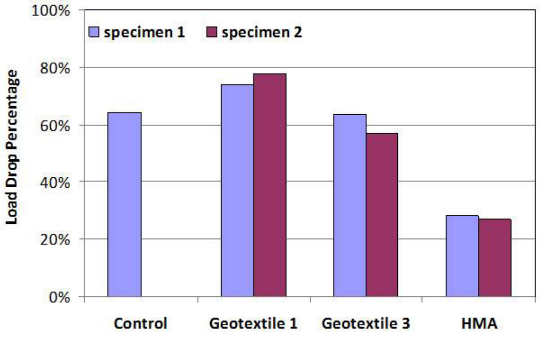


Fig. 9 Comparisons of Load Drop Percentage for Different Interlayer Types

## 6. CONCLUSIONS

The unbonded concrete overlay is commonly used with appropriate interlayer systems to prevent reflecting the distress in the existing concrete pavement into the concrete overlay. Overall, the laboratory composite beam test results did show the effect of asphalt and geotextile interlayer on the fracture behavior of composite concrete beams, although a relatively higher variation between two replicates was found. The three-layer geotextile interlayer and HMA layer both increase the peak load when the first macrocrack occurs in the top concrete beam, while the HMA interlayer causes the smallest load drop percentage after the first macrocrack. The three-layer geotextile did show better performance than the single-layer geotextile through the greater peak load and smaller load drop percentage. It indicates that the thickness of geotextile interlayer will affect the fracture behavior of unbonded concrete overlay and the thicker geotextile interlayer is recommended. Further study is needed to quantify the effect of asphalt and geotextile interlayer on the fracture behavior of unbonded concrete overlay.

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