Comparison of Life Cycle Cost for Dowel Bar Retrofit and Alternative Strategies

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Purpose

This study compares the life-cycle costs of dowel bar retrofit (DBR) against traditional M&R techniques in California. The goal is to assess under which conditions DBR is the most cost effective solution for California highways

Candidate Lane-Miles

- To warrant research into DBR, there must be a significant number of candidate lane-miles in California in which to apply DBR.
  - Sites should have low cracking and no dowels
- Based on information collected from the Caltrans, approximately **8700 lane-miles** can be considered possible candidates for DBR.
  - Because this value is large, it warrants an investigation into the cost effectiveness of DBR

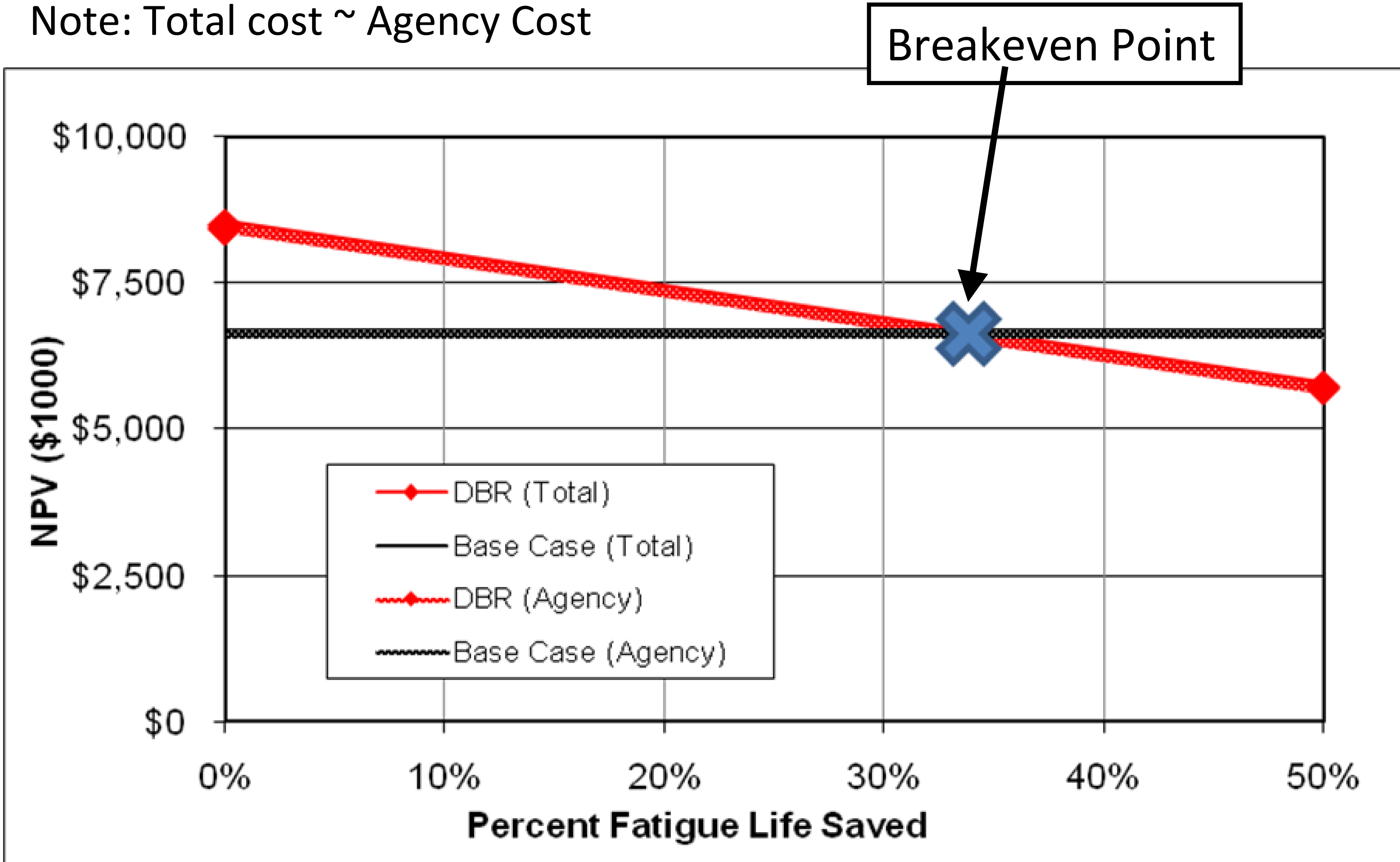
Extension of Fatigue Life from DBR

- Prior research has shown that DBR can extend the fatigue life of the pavement.
  - Linda Pierce (WSDOT)
  - Jake Hiller (U Illinois)
- Measured in % fatigue life extended
  - e.g. 33% extension on 20-yr remaining fatigue life section:
    - » 20 years + 0.33(20 years) = *26.7 years*
- Exact increase is unknown

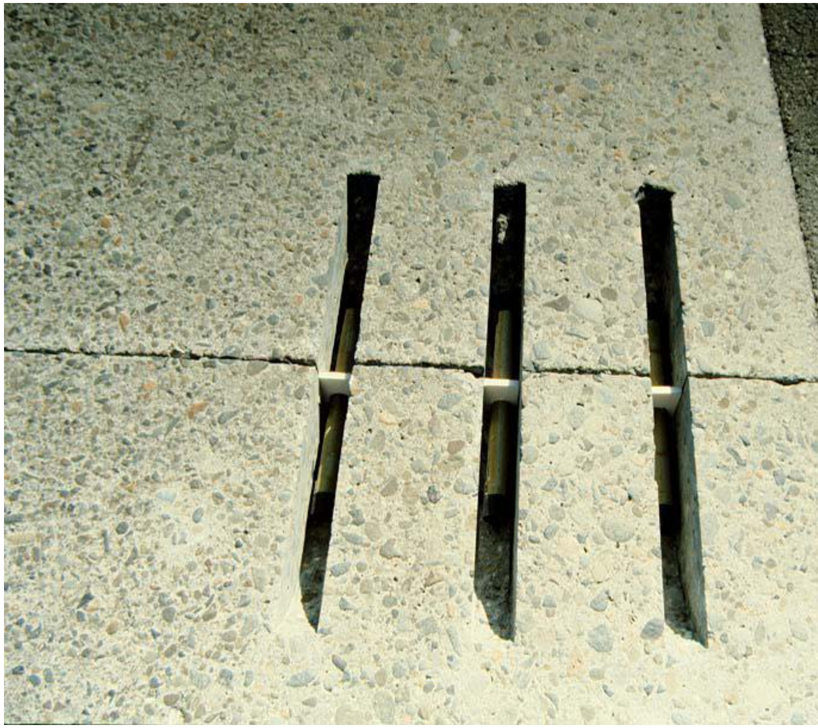
This study solves for the extension in fatigue life needed in order for DBR to become the most cost effective solution. Grinding is more cost-effective than DBR in all cases unless fatigue life is extended because of the effect of discounting.

Example: Extension of Fatigue Life

Note: Total cost ~ Agency Cost



Major Variables



- Initial remaining fatigue life
  - 10, 20 & 30 years
- Grinding life
  - Determined through MEPDG simulation
  - 10, 12, 15, 17, & 20 years
- DBR maintenance frequency
  - Determined through California site surveys
  - 0%, 3%, 6% failed slots per year
- Initial cost of DBR
  - $108k/ln-mi, $120k/ln-mi, and $132k/ln-mi

Life-Cycle Cost Analysis (LCCA)

- LCCA methodology used to evaluate using DBR versus traditional M&R strategies.
- Uses recommendations and values from the *Life-Cycle Cost Analysis Procedures Manual.*
  - Analysis period (40 years)
  - M&R activity costs
  - Overhead costs
  - Productivities
  - Other user costs inputs
  - M&R schedules

Case Study Details

- Case Study
  - 5 mile stretch of rural highway
  - 2 lanes in each direction
  - 38,500 AADT, 24% trucks
  - Based loosely on actual Kern 99 DBR site
- Note: Site details only affects user costs!
  - For agency costs, traffic should be accounted for when deciding on the estimated fatigue life remaining in the pavement (such as 10, 20, or 30 years as included in this study).
  - As will be seen, user costs are very small when compared to agency costs, making the case study details have only a minimal impact on the results.

Results: Effect of Remaining Fatigue Life (1/6)

Variable remaining fatigue lives (assumes 10-yr grinding life)

Initial Cost of DBR	DBR Maintenance (failed slots/yr)	Fatigue Life Extension Needed from DBR to be more cost-effective than grinding		
		10-Yr Fatigue Life	**20-Yr Fatigue Life**	**30-Yr Fatigue Life**
Base Case Net Present Value →		***$11.21M***	***$9.40M***	***$6.65M***
$108.0	**0%**	**71%**	**35%**	**20%**
	3%	**74%**	**38%**	**24%**
	6%	**78%**	**42%**	**28%**
$120.0	**0%**	**80%**	**41%**	**25%**
	3%	**84%**	**44%**	**29%**
	6%	**87%**	**48%**	**33%**
$132.0	**0%**	**90%**	**47%**	**30%**
	3%	**93%**	**51%**	**34%**
	6%	**96%**	**54%**	**39%**

Results (2/6)

Variable remaining fatigue lives

- As expected, pavements with longer remaining fatigue lives are better candidates for DBR.
  - Fatigue life extensions needed in order to become the most cost effective solution range from 20% to 39% (if 10 year grinding life)
- The fatigue life extension needed for pavements with shorter remaining fatigue lives is considerably higher
- DBR failure/maintenance rates significantly affect the results, especially for the 30-yr fatigue life case

* Assumes a 10 year grinding life

Results: Effect of Grinding Life with no DBR (3/6)

Variable grinding life (assumes 30-yr remaining fatigue life)

Initial Cost of DBR	DBR Maintenance (failed slots/yr)	Fatigue Life Extension Needed from DBR to be more cost-effective than grinding				
		10-Yr Grinding	**12-Yr Grinding**	**15-Yr Grinding**	**17-Yr Grinding**	**20-Yr Grinding**
Base Case NPV →		***$6.65M***	***$6.56M***	***$6.05M***	***$6.01M***	***$5.90M***
$108.0	**0%**	**20%**	**22%**	**30%**	**31%**	**33%**
	3%	**24%**	**25%**	**34%**	**36%**	**38%**
	6%	**28%**	**29%**	**40%**	**41%**	**44%**
$120.0	**0%**	**25%**	**26%**	**36%**	**37%**	**40%**
	3%	**29%**	**30%**	**42%**	**43%**	**46%**
	6%	**33%**	**34%**	**47%**	**49%**	**52%**
$132.0	**0%**	**30%**	**31%**	**43%**	**45%**	**48%**
	3%	**34%**	**35%**	**49%**	**51%**	**54%**
	6%	**39%**	**41%**	**55%**	**57%**	**60%**

Results (4/6)

Variable grinding life

- Actual life of grinding is not as important as the number of grinds performed during the remaining fatigue life
  - Notice the jump in extension of fatigue life needed between the 12-yr and 15-yr grinding life scenarios
- When multiple diamond grindings are required before the end of the fatigue life, DBR becomes a more attractive alternative

Results: Estimated loss of fatigue life from thinner slabs due to grinding (5/6)

Modeling fatigue life lost from grinding (assumes 30-yr fatigue life)

Percent Fatigue Life Lost from Grinding	**Fatigue Life Extension Needed from DBR to be more cost-effective than grinding**			
	10-Yr Grinding	**15-Yr Grinding**	**20-Yr Grinding**	**10-Yr Grinding Max 2 Grinds**
10 percent	**21%**	**38%**	**42%**	**23%**
20 percent	**15%**	**30%**	**37%**	**22%**
30 percent	**9%**	**24%**	**33%**	**22%**

Note: assumes that slab is uniformly ground 6 mm

Results (6/6)

Modeling fatigue life lost from grinding

- According to results from MEPDG runs, the material lost due to grinding will significantly reduce the fatigue life left in the pavement.
  - Even a conservative 10% life lost due to grinding will reduce the extension of fatigue life needed from 29% to 21% for a 10-yr grinding cycle (3% slot failure, $120k/ln-mi, 30 year fatigue life)
- Actual reduced fatigue life is highly variable depending upon traffic, climate, pavement structure, and grinding depth.

* Assumes 3% DBR slot failure per year, $120k per lane-mile DBR construction cost, and 30 years of remaining fatigue life.

Conclusions (1/2)

- Some extension of fatigue life is needed in order for DBR to become a cost effective alternative
  - There were no cases where the extension of fatigue life necessary was less than zero.
- Agency costs controlled the analysis
  - In most scenarios, the user costs were two orders of magnitude smaller than the agency costs

Conclusions (2/2)

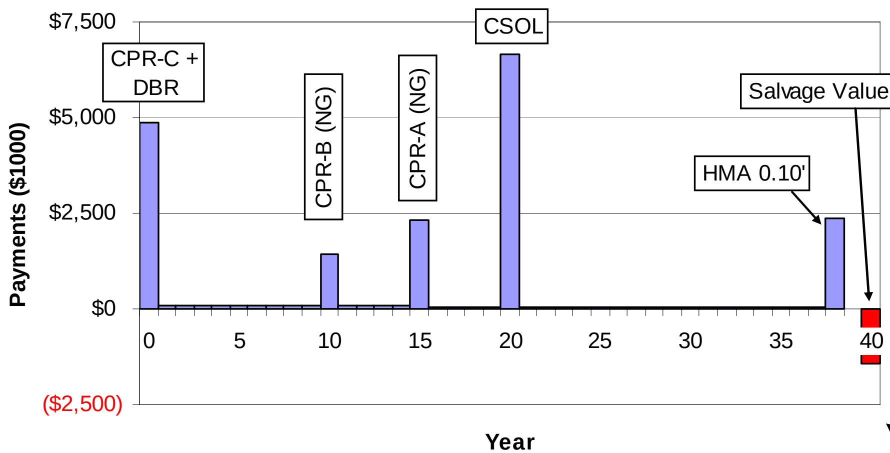
- DBR is best applied…
  - When pavement has long remaining fatigue life
  - When pavement requires multiple grindings over its life
  - In situations where the discount rate is low
  - When the initial construction cost of DBR is low
    - Potentially applicable when using 3 dowels per wheelpath instead of 4, as assumed here
  - When DBR slot failure rates are low

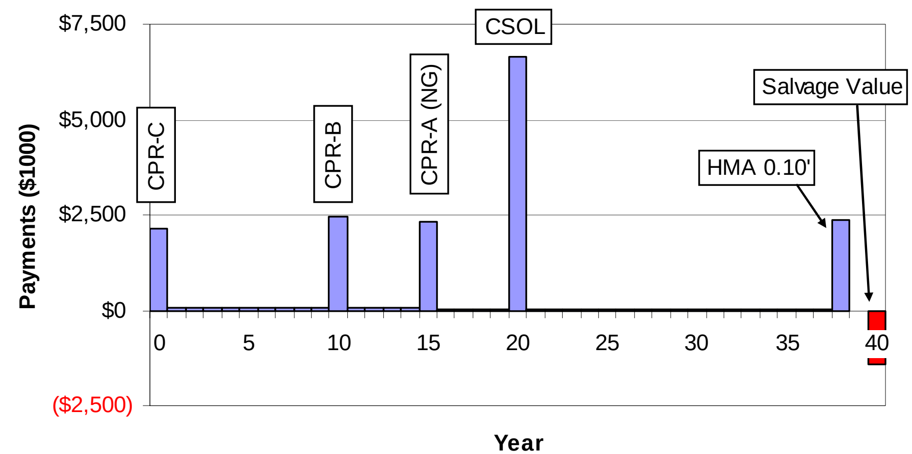
Reports will be at www.its.berkeley.edu/pavementresearch

Questions ???

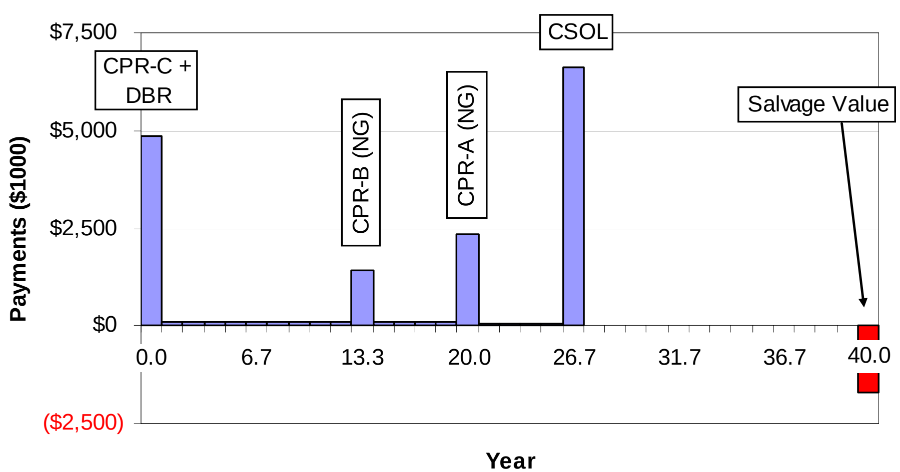
Example Cost Flow Diagrams

Assumes 20 years of remaining fatigue life and 10 year grinding life





Base Case



DBR (0% fatigue life extension)

DBR (33% fatigue life extension)