BRT and Concrete

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Introduction

- Typical BRT axle load distribution (max 13 ton/axle).
- The whole spectrum of concrete pavement options are considered with traffic loading away from the edge.
- Emphasis is on thin reinforced concrete pavements.
- Design program cncPAVE used to illustrate typical design options and the relative performance of each.
- Analyses based on the same slab support system including stabilised subbase, erosion of the subbase and typical bond between subbase and slab.
- Typical costs are used to compare concrete pavement designs but obviously will change from site to site.

Typical Pavement Types

- Plain Jointed without any reinforcement and shrinkage joints every ± 4.5m.
- Dowel Jointed with steel dowel bars in shrinkage joints every ± 4.5m.
- Continuously Reinforced without any joints but longitudinal steel bars forcing shrinkage cracks to develop at about 1.5m spacing.
- Ultra-thin Continuously Reinforced without any joints but enough longitudinal steel bars + steel fibres to force shrinkage cracks to develop every about 0.4m.
- Construction joints on all concrete options.

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Typical BRT Designs

(Using cncPAVE with same traffic & support)

Type	Average Thickness / Strength (fc)
Jointed (J)	270mm / 5 MPa
Dowel jointed (DJ)	205mm / 5 MPa
Continuously reinforced (CR)	175mm / 5 MPa
Ultra-thin CR (UTCR)	70mm / 9 MPa
Ultra-thin CR (UTCR)	50mm / 12 MPa

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Typical BRT Designs (continue)

Type	E80’s	Reinforcement
270mm J	30	None
205mm DJ	30	32mm @ 250mm at joints
175mm CR	30	16mm @ 170mm spacing
70mm. UTCR	30	13mm @ 100mm +60kg fiber
50mm. UTCR	30	6mm @ 50mm +60kg fiber

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Typical Performance (cncPAVE)

Type	Crack width	Shattered	Pumping	LC cost.*
270mm J	1.9mm	5%	2.8%	1.00
205mm DJ	2.2mm	5%	1.7%	0.92
175mm CR	1.0mm	0.8%	0.4%	0.84
70mm. UTCR	0.3mm	0.75%	32%	0.82
50mm. UTCR	0.2mm	0.65%	34%	0.78

* Relative life cycle cost calculated for 40 year period

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Implications of Performance

- Limits of performance indicators (%shattered, %pumping) in line with requirements from clients.
- Un-reinforced slabs are allowed to show more failures; implies easier to repair?
- Thin concrete designs with steel fibres show more pumping (more flexible).
- Ultra-thin designs requires more stringent control at time of construction (variation).
- Buckling may become an issue if ultra-thin designs are considered.

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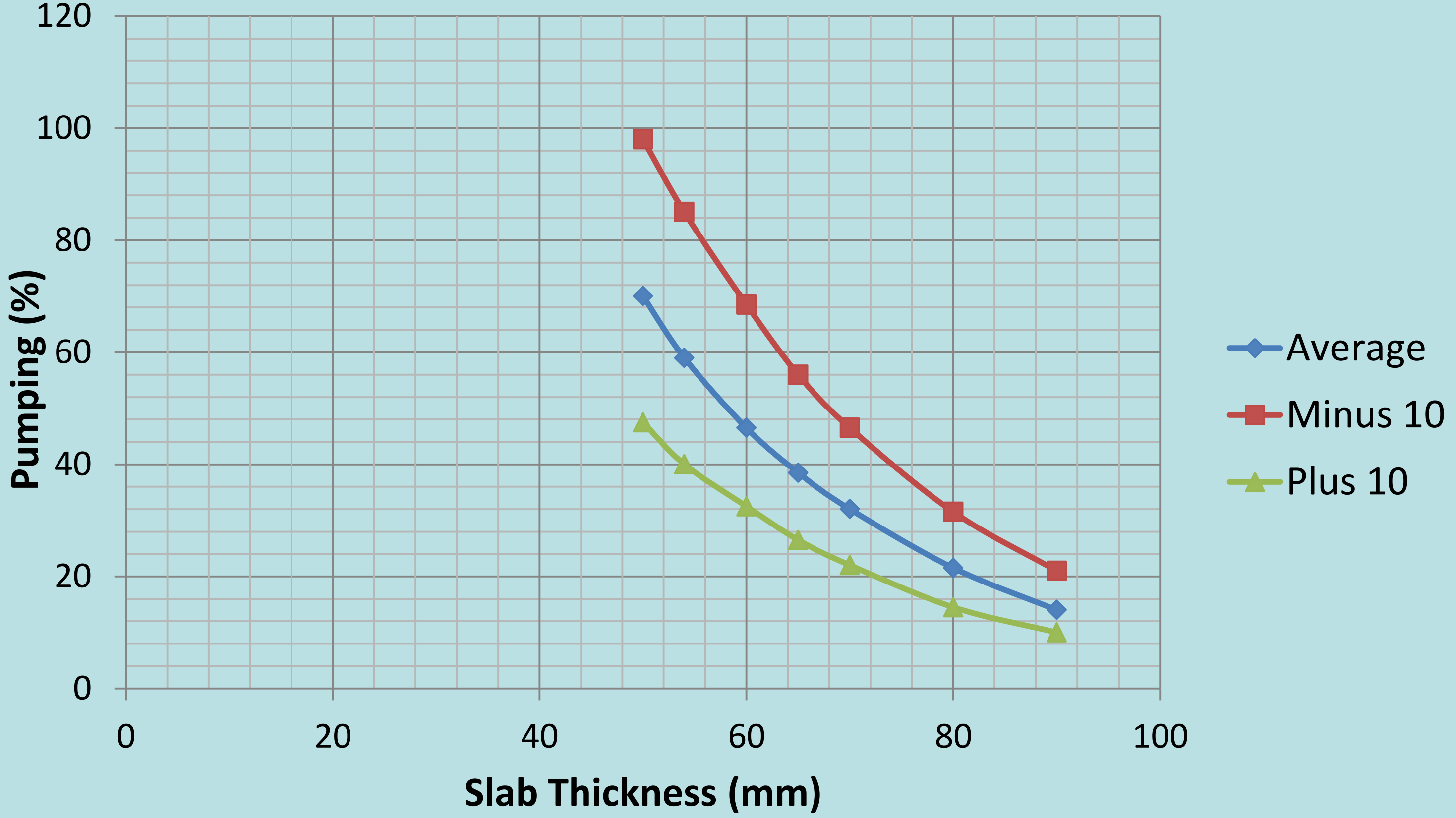
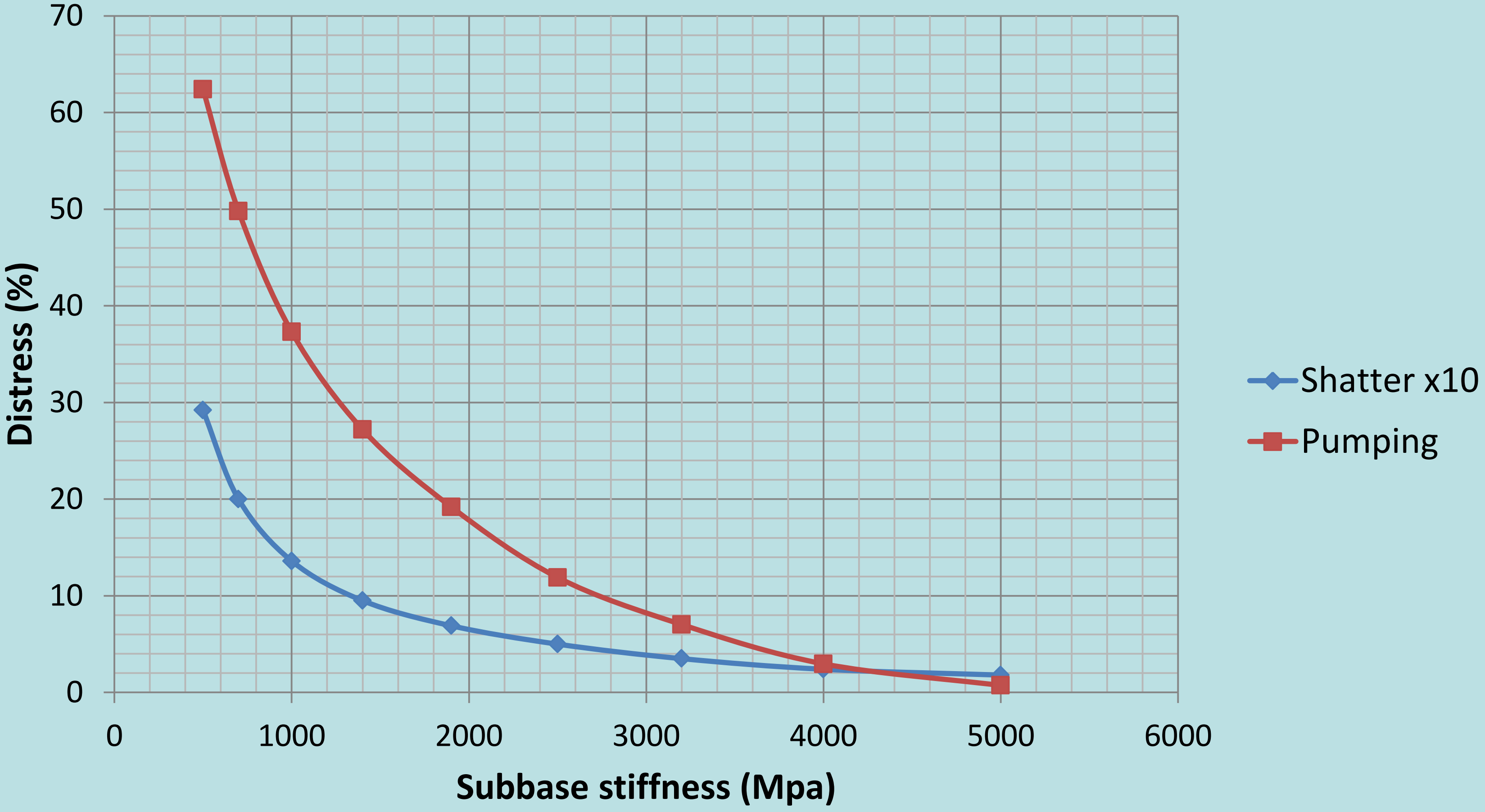
Effect of Variation in UTCRC Thickness on Pumping (f=9MPa)



Relative Effect of Subbase Quality on Distress (f=9, h=70)



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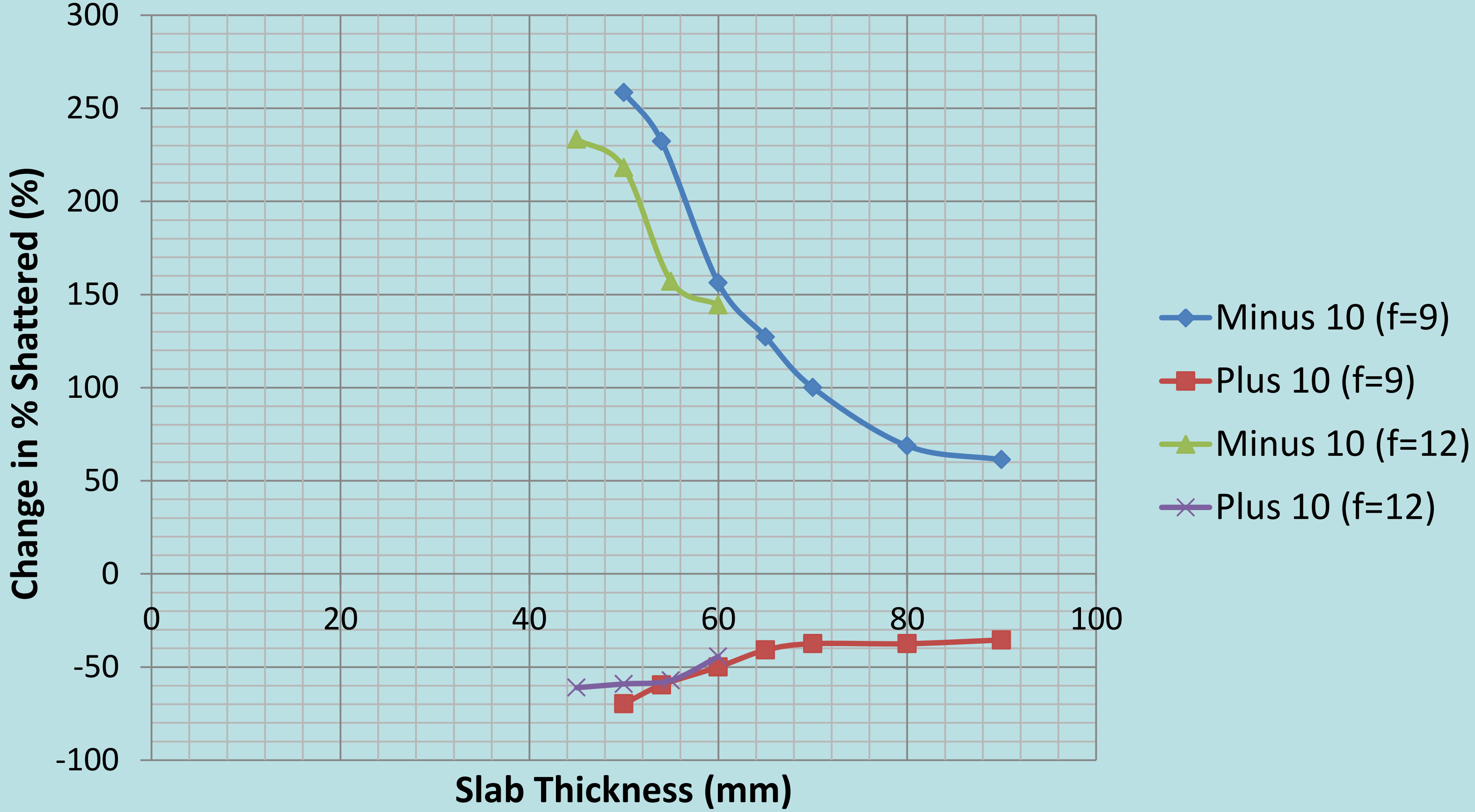
Effect of Variation in UTCRC Strength (f) and Thickness (± 10mm) on Shattered



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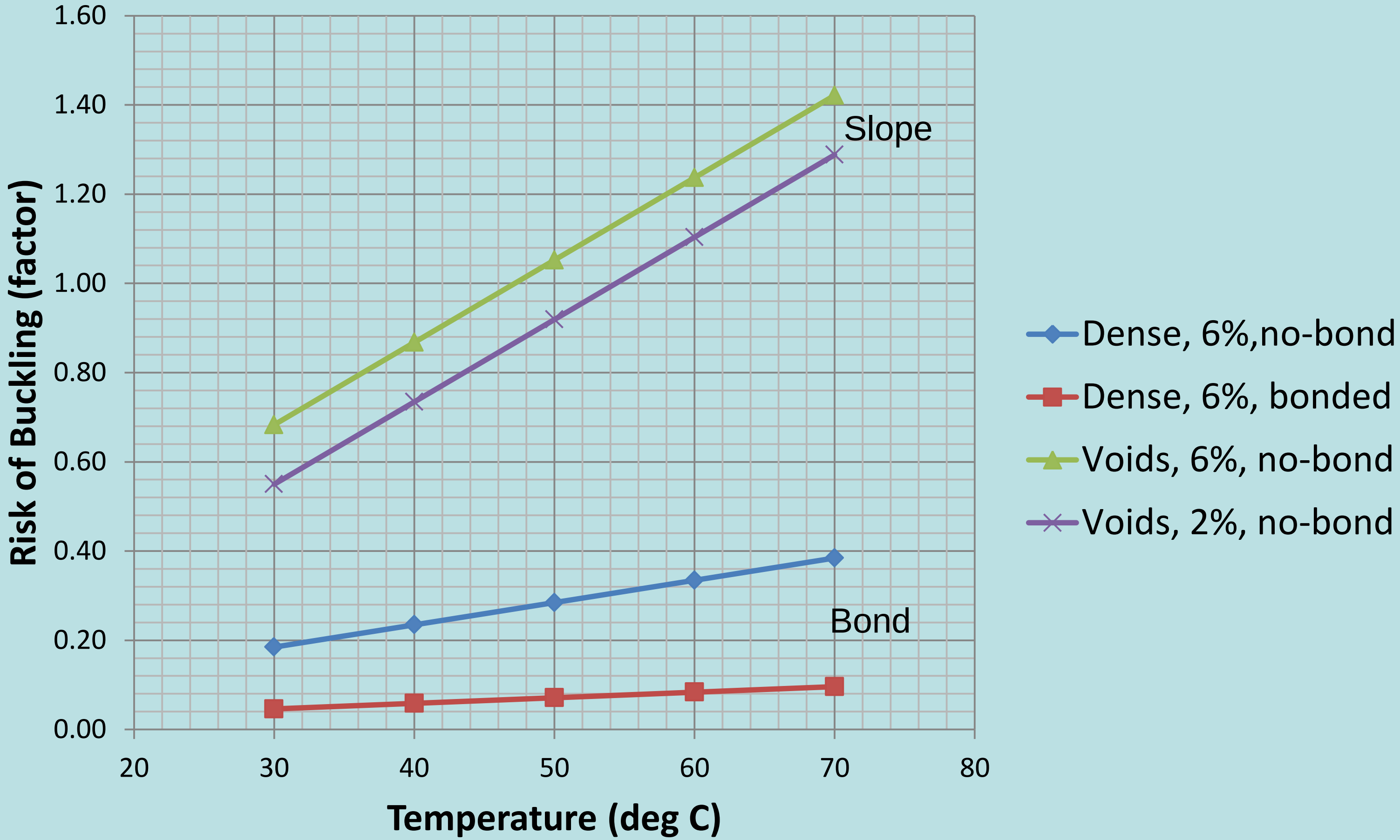
Buckling for 50mm (f=12MPa) Slab: Depends on densification, slope and bond



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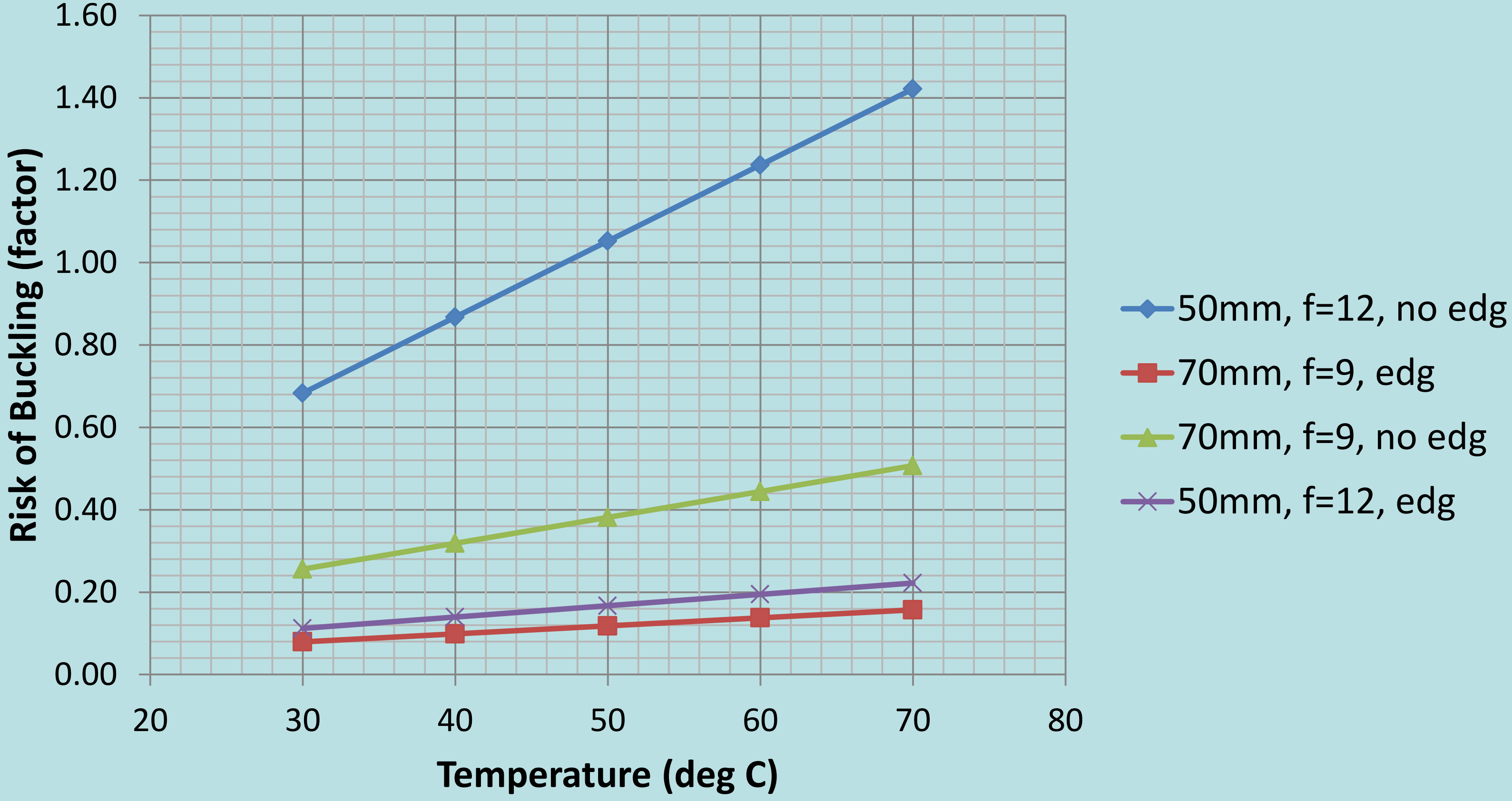
Buckling of Un-bonded Slab with Voids: Depend on h and edge thickening



Important Aspects to Consider

- Higher axle loading under BRT traffic increases the importance of load transfer at joints. (J vs CR)
- Jointed Concrete Pavements with or without dowels in the joints seems to be relatively less cost effective than Continuously Reinforced Concrete Pavements under BRT loading.
- 50mm Ultra-thin Continuously Reinforced Concrete with steel fibres seems to be the most cost effective.
- All Continuously Reinforced Concrete Pavements, including UTCRC, are more difficult to repair but can be overlaid more successfully (little reflection of cracks and joints).

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Important Aspects to Consider

- Thinner pavements require higher strength concrete and also result in relatively higher deflection under traffic.
- Stiffer and more erosion resistant subbases are recommended in order to enhance the performance of thinner pavements. (Thinner slabs imply higher stress on the surface of the subbase).
- Thinner pavements also require more stringent control at the time of construction. (Reduce variation in thickness and also ensure well compacted concrete).
- Avoid surface cracking which may develop with too much water in the concrete, windy conditions, hot and dry weather and poor curing practice.

Important Aspects to Consider

Risk of buckling increases when:

- Ultra-thin designs are considered, especially when high strength concrete is used (thermal characteristics).
- Air temperature tends to get higher than 60 C.
- Slab thickness is less than 60mm.
- Edge thickening is absent at slab thickness less than 50mm
- Concrete is not well compacted (honey-combing).
- Poorly designed and constructed construction joints.
- Longitudinal road slopes are greater than 4% down-hill (heavy trucks breaking). Research?
- Loss of bond between slab and subbase.

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Summary and Conclusions

- Thinner reinforced concrete pavements seems to be more cost effective than thicker jointed concrete pavements (BRT).
- Reinforced pavements show smaller crack widths, less ingress of water and can be overlaid in future at a low risk of reflection cracking.
- Thicker pavements are however easier to build and maintain.
- Thinner pavements need to be designed for a lower risk of structural failures and also need to be well constructed.
- Very thin pavements without edge thickening can buckle at high temperatures, steep gradients, when loss of bond between subbase and slab occurs and if not well constructed.

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