
POLYURETHANE RESIN (PUR) INJECTION FOR ROCK MASS STABILIZATION

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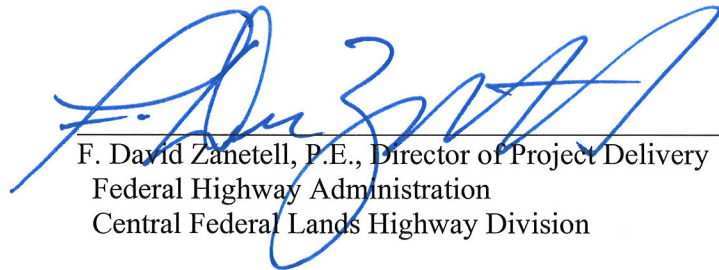


**Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228**

FOREWORD

The Federal Lands Highway (FLH) of the Federal Highway Administration (FHWA) promotes development and deployment of applied research and technology applicable to solving transportation-related issues on Federal lands. The FLH provides technology delivery, innovative solutions, recommended best practices, and related information and knowledge sharing to Federal agencies, Tribal governments, and other offices within the FHWA.

The primary objective of this study is to provide specific guidance on the appropriate application and use of polyurethane resin (PUR) injection for stabilizing jointed and fractured rock masses and constructed rock structures. Features evaluated in this study included a previously rock-bolted tunnel portal, jointed rock slope and historic dry-stack stone retaining wall. It is envisioned that this technology will provide both primary and supplemental rock mass stabilization and structure preservation options for a broad range of applications, encompassing geotechnical, historic and archeological structures.



F. David Zanetell, P.E., Director of Project Delivery
Federal Highway Administration
Central Federal Lands Highway Division

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16. Abstract The Federal Lands Highway (FLH) of the Federal Highway Administration (FHWA) recently investigated the application of polyurethane resin (PUR) injection as a rapidly deployed, cost-effective ground and structure stabilization method. Application objectives included the preservation of historic, cultural and other environmentally sensitive natural and man-made features, while maintaining the original visual characteristics and aesthetic appeal. Most recently, in cooperation with the Colorado Department of Transportation (CDOT), FLH completed full-scale PUR demonstration projects at a historic tunnel located along highway SH 14 in the scenic Poudre Canyon west of Ft. Collins, CO, and at a dry-stack stone masonry retaining wall supporting highway SH 149 along the Rio Grande River northwest of South Fork, CO. The Poudre Canyon demonstration involved PUR injection and stabilization of a previously bolted section of the western tunnel portal, where annual freeze/thaw cycles and rock mass creep toward the adjacent Cache La Poudre River were contributing to rock mass instability. The South Fork demonstration involved PUR injection within a culturally-sensitive dry-stack stone masonry wall that was progressively failing. In addition to the FLH sites, CDOT also contributed PUR injection data from a recent rock slope stabilization project along highway US 6 in Clear Creek Canyon just west of Golden, CO. Based on the "lessons learned" from these investigations, application guidance has been developed for the selection of polyurethane resin products and injection methods to (1) stabilize failing rock-masses (e.g., rock slopes, unique rock promontories, escarpments), and (2) preserve aging and/or deteriorating man-made structures (e.g., historic retaining walls, archeological structures).			
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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	Millimeters	mm
ft	feet	0.305	Meters	m
yd	yards	0.914	Meters	m
mi	miles	1.61	Kilometers	km
AREA				
in ²	square inches	645.2	Square millimeters	mm ²
ft ²	square feet	0.093	Square meters	m ²
yd ²	square yard	0.836	Square meters	m ²
ac	acres	0.405	Hectares	ha
mi ²	square miles	2.59	Square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	Milliliters	mL
gal	gallons	3.785	Liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	Grams	g
lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	Lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	Newtons	N
lbf/in ²	poundforce per square inch	6.89	Kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	Inches	in
m	meters	3.28	Feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	Miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	Hectares	2.47	Acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	Milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	Gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	Ounces	oz
kg	kilograms	2.202	Pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	Poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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