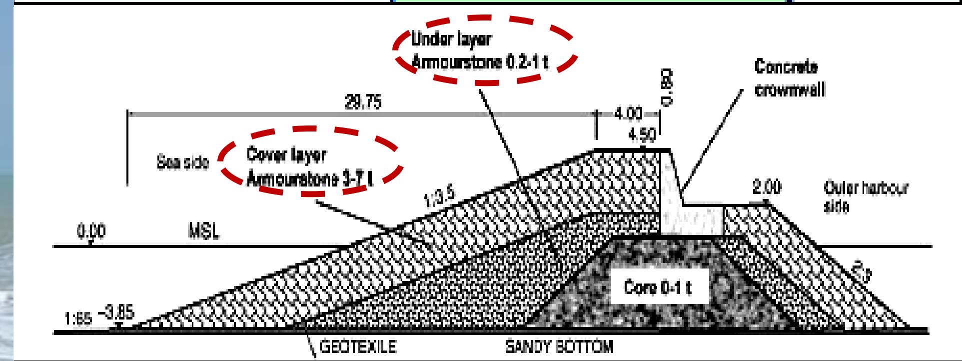
Service Life Prediction of Granite Armourstone: A Case Study of Thung Wang Granite, Songkhla

Pongpant Pantpong
Danupon Tonnayopas
Chitpon Aedpan

Department of Mining and Materials Engineering
Faculty of Engineering
Prince of Songkla University

Introduction

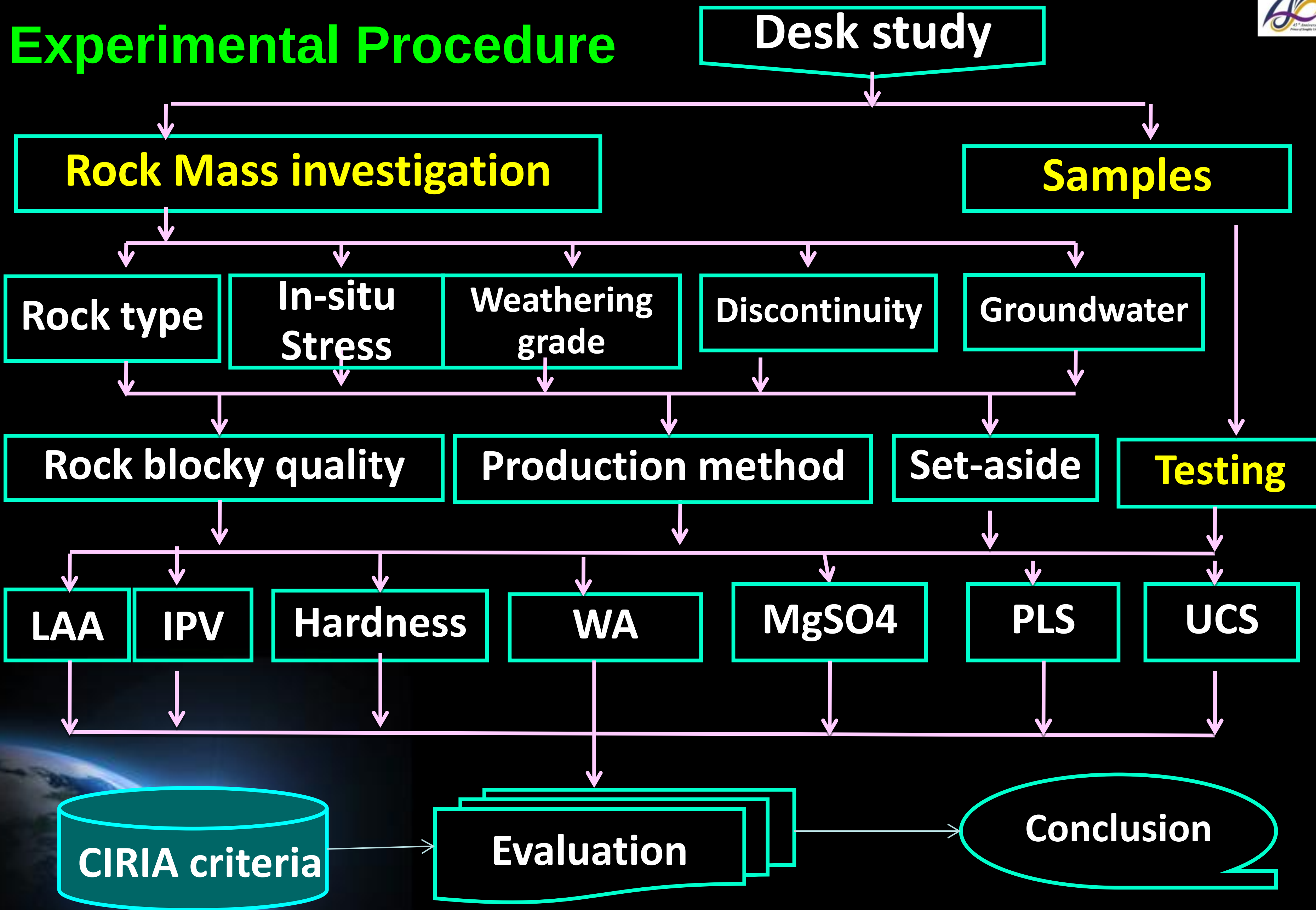


Purpose of Study

A study conducted into the quality of Thung Wang granite as a source of armourstone

To quantify the reduction in armourstone mass over the design life of a coastal structure

Experimental Procedure



Rock mass in Thung Wang quarry

Index properties of the armourstone

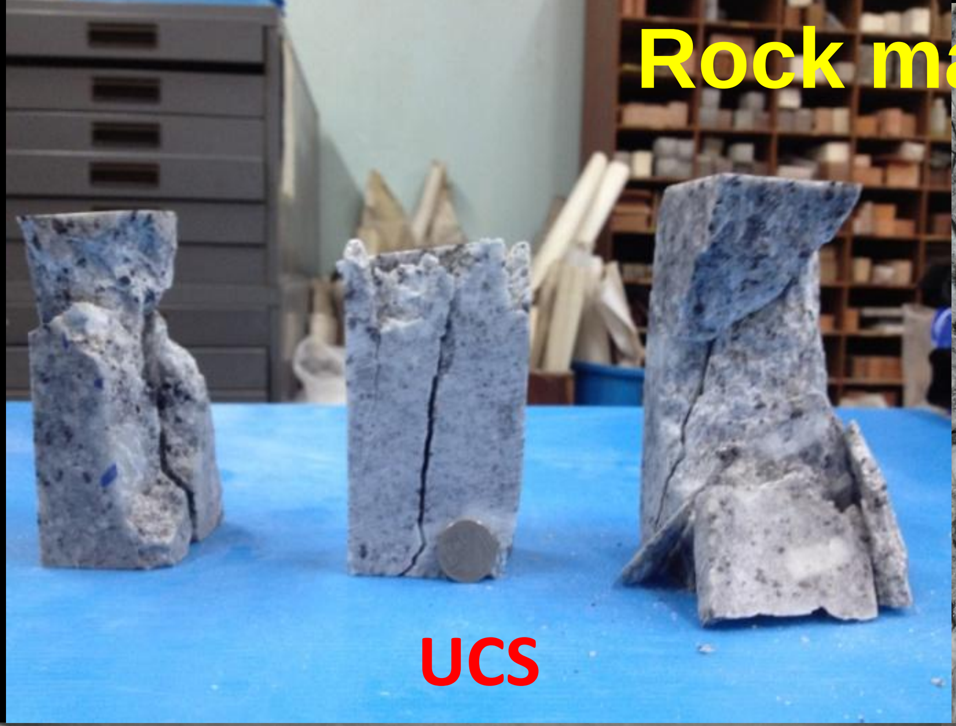
CIRIA/CUR classification for Thung Wang Quarry

Criteria	Description	CIRIA Rating
Lithological classification	Biotite granite to pophyritic granite	Excellent
Weathering grade	I Fresh	Marginal
Groundwater condition	Moist and completely dry	Marginal

CIRIA/CUR classification for Thung Wang Quarry

Criteria	Description	CIRIA Rating
Production method	Conventional blasting	Marginal
Stone shape & weathering grade	10-15% of stones LT>3, 95% of stones Grade II	Marginal
Set aside	Approx. 1 month	Excellent

Rock material testing



Index properties of the Thung Wang granite

Property	Range (mean)	CIRIA rating
Dry density, t/m^3	2.51-2.59 (2.54)	Good
Water absorption, %	0-0.93 (0.4)	Excellent
Compressive strength, MPa	105-115	Good
Point load index, MPa	2-6 (3.57)	Good
Los Angeles abrasion, %	39-40	Poor
$MgSO_4$ soundness, %	0.03	Excellent
Impact value, %	17.97-20	None
Shore hardness	845	None

Lienhart (2003) presented the recommendation is to use the Meteorological Climate Weathering Intensity (*MCWI*) index

$$MCWI = (a/b)\times(d/365)\times(e/c)\times(g/f)\times h \ldots\ldots\ldots (1)$$

where *a* is mean (max) – mean (min) temperature range over several years, *b* is mean annual temperature, *c* is mean number of days max temp > freezing, *d* is mean number of days min temp ≤ freezing, *e* is extreme max and min temperature range over several years, *f* is mean number of days with precipitation > 0.25mm, *g* is annual precipitation in cm, *h* is total normal degree-days, base 18°C

Fractions of original mass ranges calculated for Thung Wang rock as armourstone in 50 years Initial rock size (M_0) Fraction of original mass in 50y (M/M_0)

Criteria	CIRIA rating				Rating value	Weight ing	Weighted rating
	4	3	2	1			
Lithological classification	√				4	58	2.91
Regional in-situ stress			√		2	73	1.83
Weathering grade			√		2	73	1.83
Discontinuity analysis			√		2	95	2.38
Groundwater condition			√		2	73	1.83
Production method			√		2	95	2.38
Rock block quality			√		2	80	2.01
Set-asisde	√				4	73	3.67
Mass density			√		3.0	80	3.01
Water absorption	√						

Table Fractions of original mass ranges calculated for Thung Wang rock as armourstone in 50 years Initial rock size (M_0) Fraction of original mass in 50y (M/M_0)

Criterria	CIRIA rating				Rating value	Weighting	Weighted rating
	4	3	2	1			
UCS		√			3.5	88	3.87
Schmidt impact index	√						
PLS			√		1.5	88	1.66
Los Angeles abrasion							
$MgSO_4$ soundness	√				4	80	4.02
				Sum		956	31.41
Note: Excellent = 4		Good = 3		n		12	12
Marginal = 2		Poor = 1		Mean		79.67	2.62

Determination of the intrinsic resistance to mass loss

$$k_s = 0.032AQD^{-2.0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$k_s = 4.12 \times 10^{-5}MDE^{1.485} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

$k_s = 3.52 \times 10^{-3}$ to 4.66×10^{-3}

Fractions of original mass ranges calculated

$$X = X_1 \times X_2 \times X_3 \times X_4 \times X_5 \times X_6 \times X_7 \times X_8 \times X_9 \quad \text{.......... (4)}$$

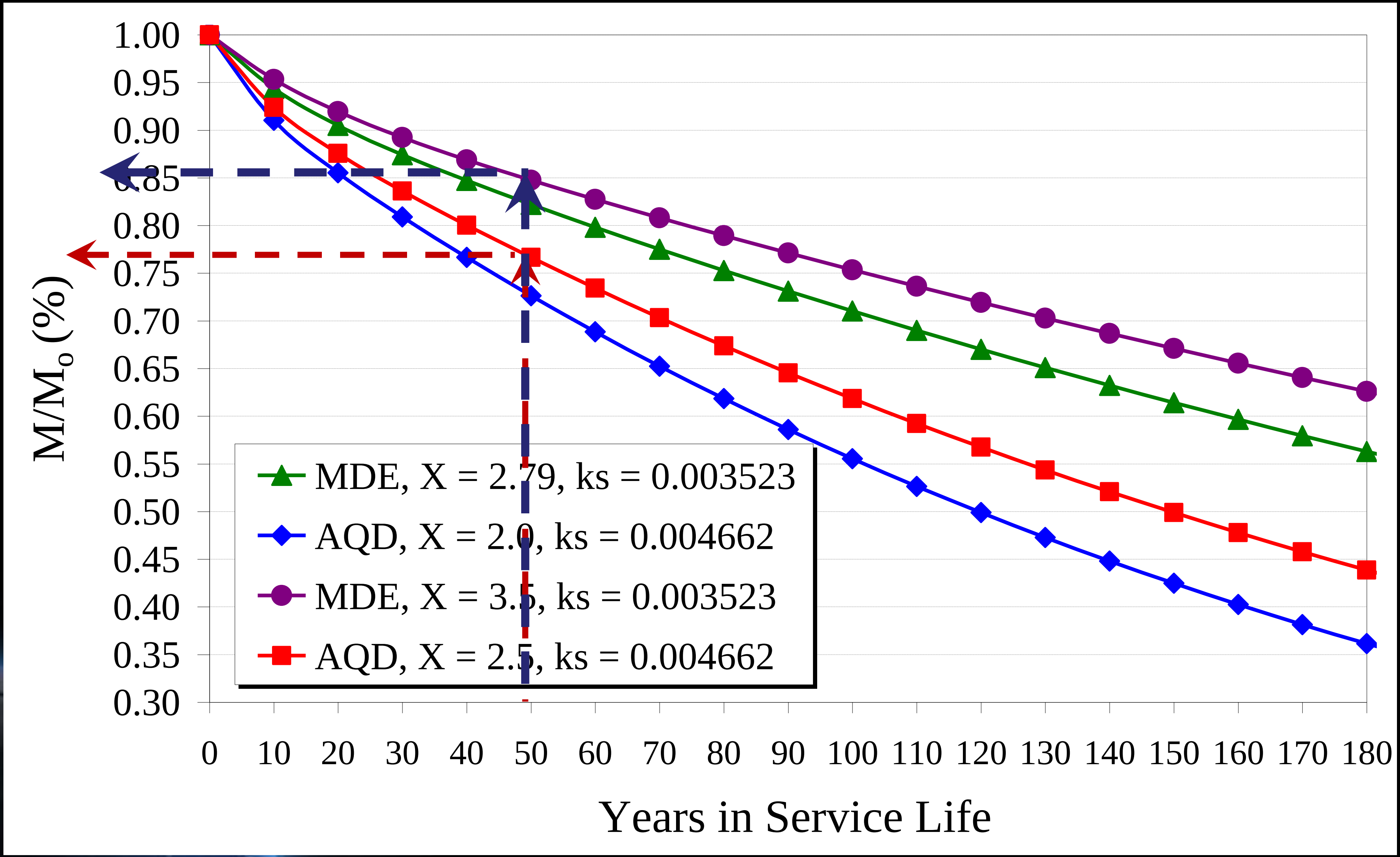
Criteria	Description	Rating value	
		AQD	*MDE*
X_1	Rock size	0.63-0.79	0.63-0.79
X_2	Rock grading	1.64	1.64
X_3	Rock shape	1.5	1.5
X_4	Wave energy	2.6	2.6
X_5	Zone of structure	1.0	1.4
X_6	Climate	1.5	1.5
X_7	Water borne attrition	1.0	1.0
X_8	Concentration of wave attack	0.3	0.3
X_9	Mobility of armuorstone	1.1	1.1

Equivalent Wear Time Factor is calculated as the product of each of these parameters via Equation 5

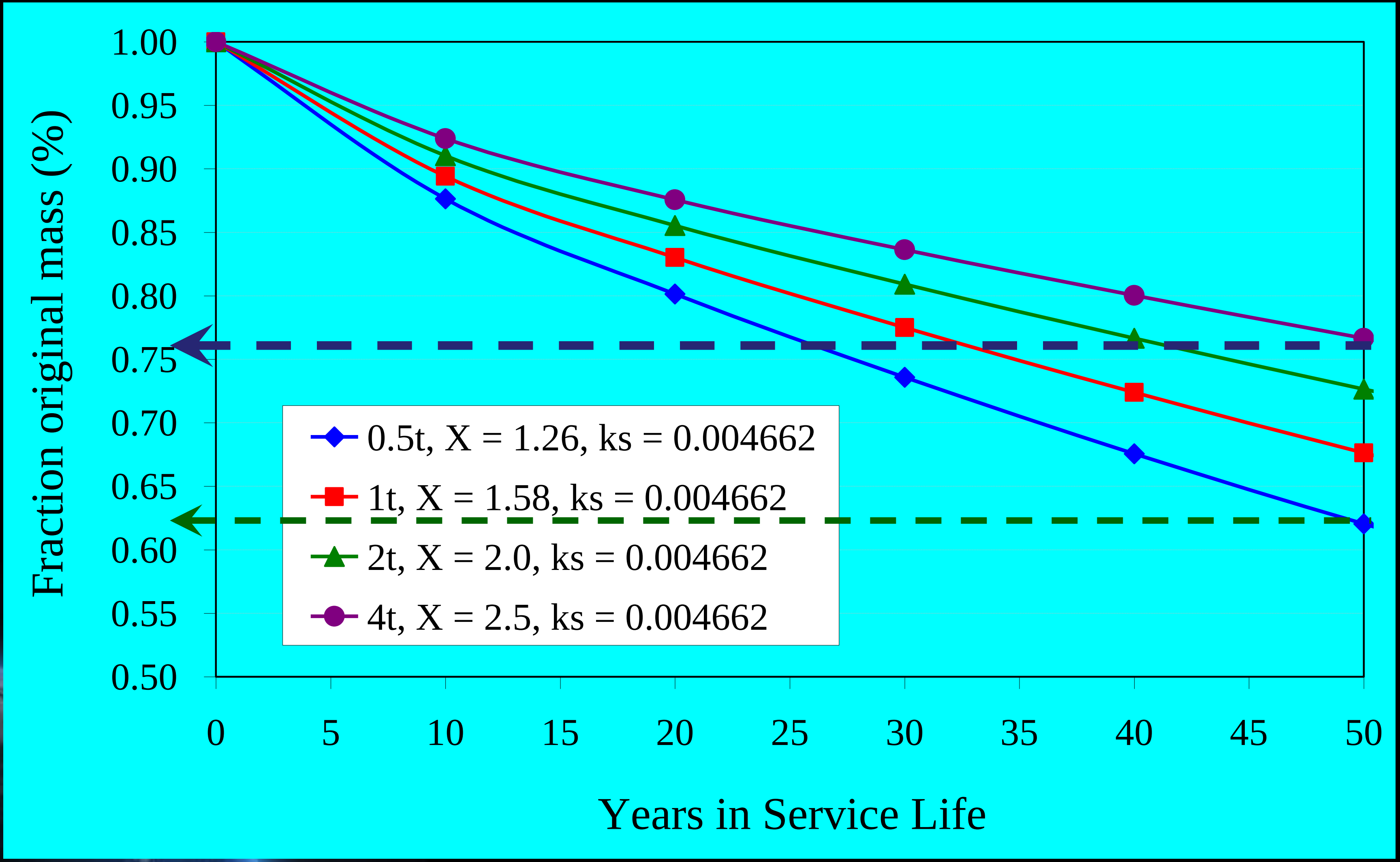
$$M/M_0=0.05\exp[-30(k_sT/X)]+0.95\exp[-k_sT/X] \quad ..... \quad (5)$$

where M is nominal mass of armourstone at time T, M_0 is initial mass of armourstone; k_S = intrinsic resistance to mass loss; X = equivalent wear time factor; T = time since installation (years)

Predictly degradation envelopes based for 2 and 4 tonne armour on the *AQD* and *MDE* methods



Degradation envelopes for different rock sizes based on the *AQD* method.



DISCUSSION & CONCLUSIONS

1. In the field observations by checking the produces of the granite in the Thung Wang quarry is lowly variable and the highland reveal that the granite showed marginal quality armourstone. The conditions that the rock is subject to are mild in terms of wave attack but the high salinities and temperatures in the region are likely to accelerate surface spalling and crumbling.

2. The *AQD* and *MDE* models were applied to the known parameters for Thung Wang rock, the *MDE* method suggests lower degradation rates than the *AQD* method. The results obtained on samples show significant variation in the resistance to wear. This is mainly due to the fact that the quality of the local rock varies within the same quarry. Because the *MDE* method relies uniquely on the *MDE* coefficient for determining the intrinsic resistance to mass loss k_s, the

3. it is considered that with the available data the *AQD* method provides a better general description of the rock resistance weathering in this case. Based upon the results of this model, it is proposed that concept designers should allow for M/M_0 of 0.62 for 0.5 tonne armour, and 0.755 for 1 tonne armour for a 50 year design service life. Inside for M/M_0 of 0.726 for 2.0 tonne armour, and 0.766 for 4 tonne armour for a 50 year design service life.

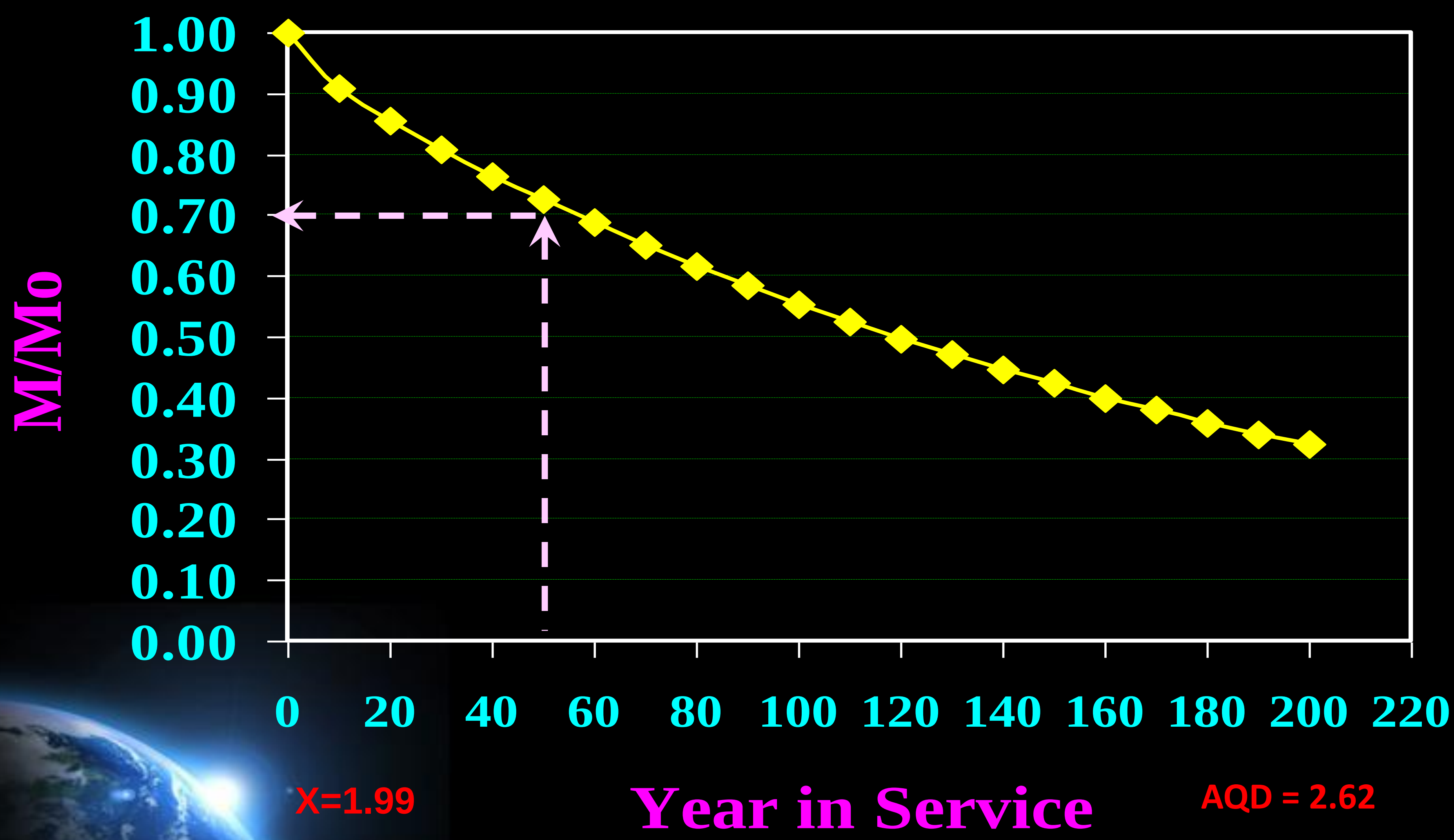
4. For the Thailand’s southern Gulf east coast from Prachuap Khiri Khan to Narathiwat. Designers should therefore carefully verify the applicability of these proposed degradation rates and refer to site specific investigation in order to correctly apply the degradation models on a case-to-case basis. Design criteria such as slope, grading envelope curves, stability number, frequency of storm, earthquake intensity could alter significantly the proposed degradation predictions. Likewise site conditions such as tidal range, wave height etc) could differ throughout south Thailand, between the East (Andaman Sea) and the West (Gulf of Thailand) coasts. This could also lead to different predicted degradation rates.


Thank you for your attention

Fractions of original mass ranges calculated

Criteria	Description	Rating value	
		AQD	MDE
X_1	Considered typical primary armour in Songkhla of between: 0.5, 1.0, 2.0 and 4.0 tonnes.	0.79-0.63	0.79-0.63
X_2	Narrow graded armour is assumed, with (M_{85}/M_{15}) 1/3 ≈ 1.2	1.64	1.64
X_3	Assumed irregular based on inspection	1.5	1.5
X_4	The 1 in 50 year H_s is estimated to be approximately 2.5 m for Songkhla's north coasts. Based on such small waves a value of 4.0 is deemed reasonable.	2.6	2.6
X_5	Assumed worst case (intertidal)	1.0	1.4
X_6	Used Latham [3] instead of CIRIA [7]. Assumed to be a hot and wet climate with water absorption < 2%	1.5	1.5
X_7	Would generally be no waterborne attrition agents due to mild wave conditions, but the case of waterborne attrition around Songkhla coast by sand and silt.	1.0	1.0
X_8	Revetment slope angle is commonly 1 in 2.5 or gentler. Tidal range is generally < 2 m throughout the Gulf coast of Thailand	0.3	0.3
X_9	Assumed static design concept (generally the case for permanent structures in Songkhla), assuming Im50 = 2.56%	1.1	1.1

Armourstone 2 tons by AQD method



Armourstone 2 tons by MDE method

MDE = 20

X = 2.79

Arrmourstone 4 tone by MDE method

X=3.5

MDE=20