Predicting Condition of Reinforced Concrete Beams with Shear Cracks using Machine Learning

Presenter :

Rodrigo Castillo, Ph.D. candidate

Co authors :

Pinar Okumus, Ph.D.
Negar Elhami Khorasani, Ph.D.
Varun Chandola, Ph.D.

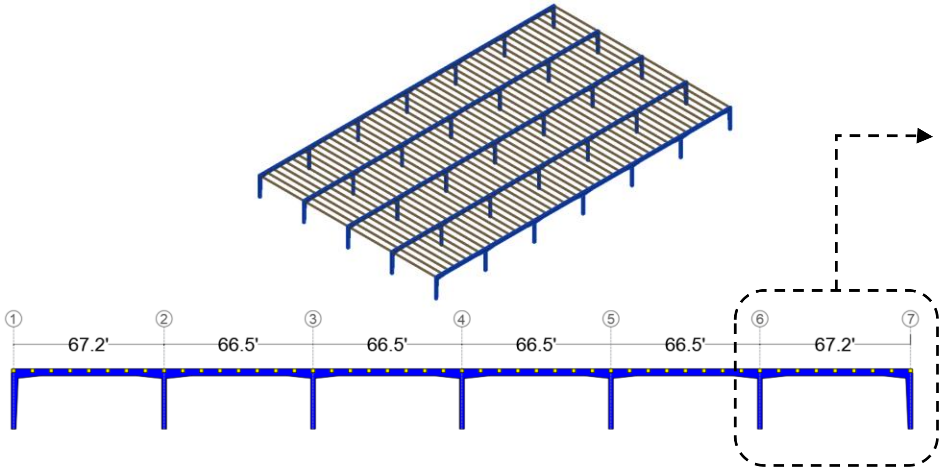
University at Buffalo, NY

Department of Civil Structural and Environmental Engineering

MOTIVATION

Ohio, 1955

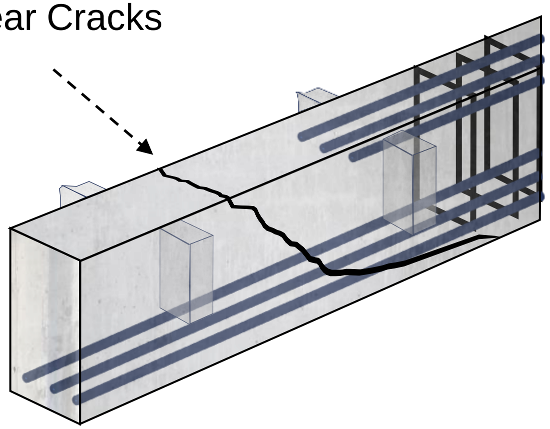
Source: Shelby Museum of History.



Wilkins Wilkins Warehouse

Source: ACI-ASCE Committee 326 1962

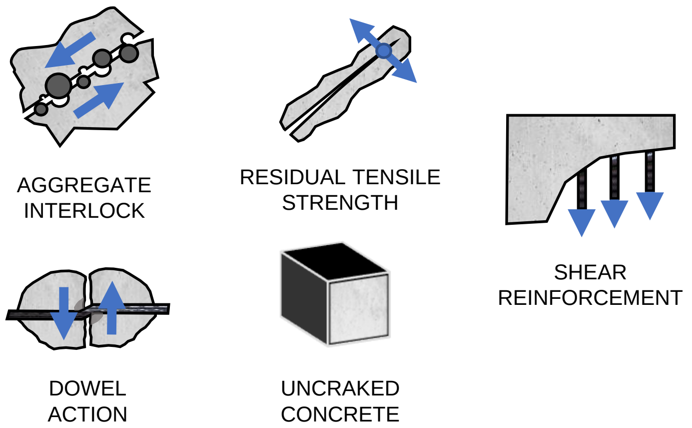
Shear Cracks



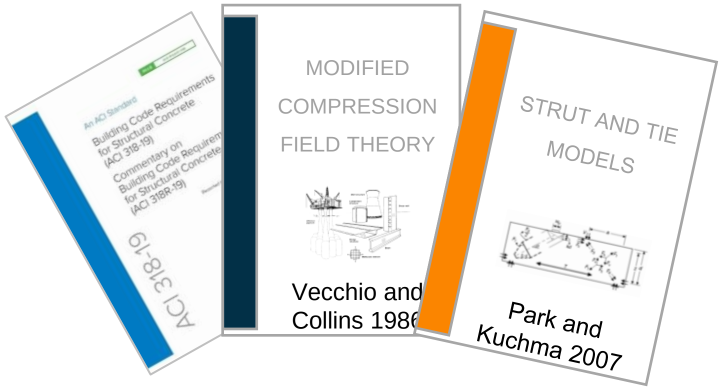
Adapted from: Deifalla 2021

Source: Cuenca 2014

Shear Failure Wilkins Warehouse



ACI-ASCE Committee 326 (1962)



Accuracy varies

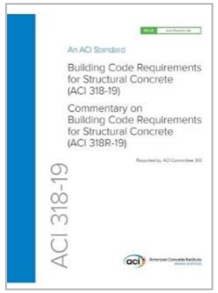
MOTIVATION

Can we estimate the shear condition in a timely manner?

US Bridges: 619,588 (40% RC)

Need rehabilitation: 223,972 (36%)

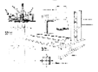
Source: ARTBA (2022)
FHWA-HIF-18-061 (2019)



NO

SHEAR STRENGTH ONLY

MODIFIED COMPRESSION FIELD THEORY



Vecchio and Collins 1986

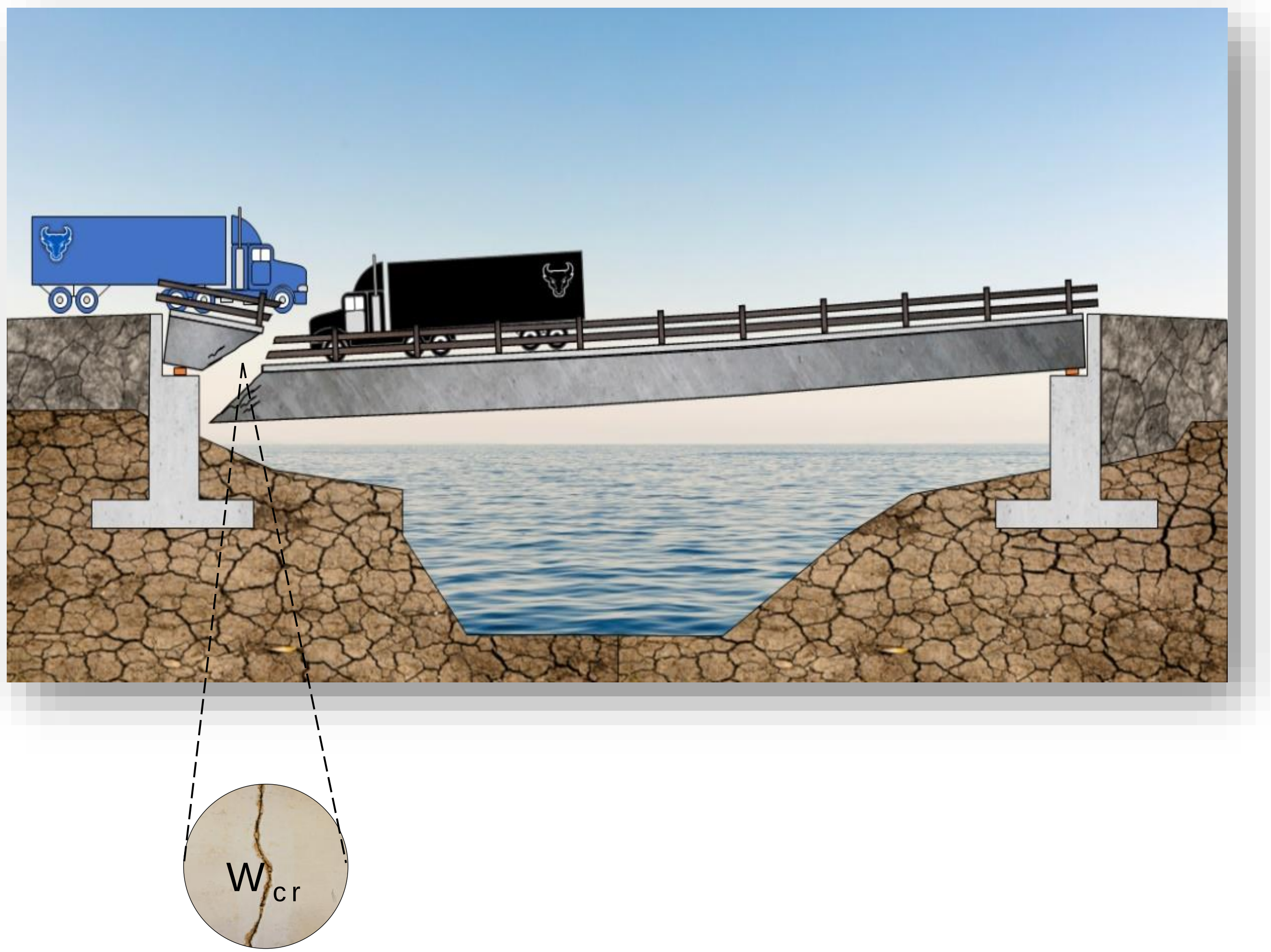
YES/ NO

EXPERTISE AND MODELING TIME CONSUMING

MACHINE LEARNING

YES

EASY FAST ACCURATE

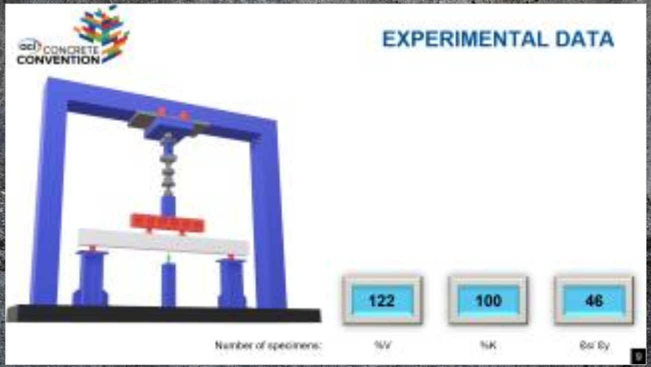


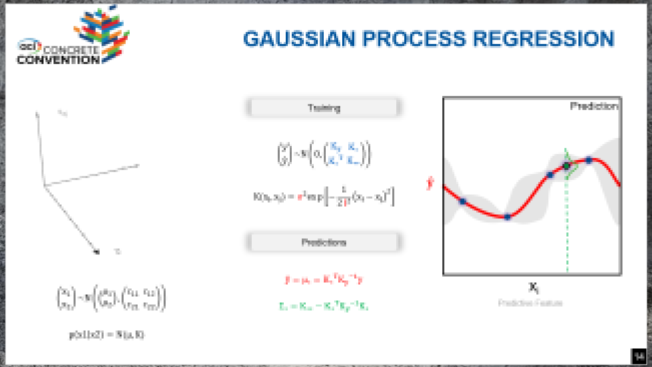
OBJECTIVE

Predict the shear, stiffness and stirrup strain histories

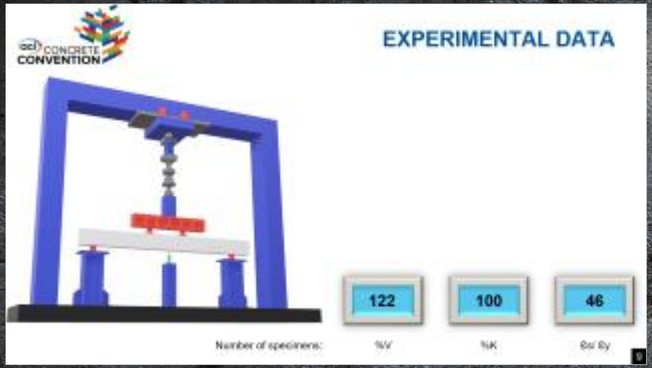
as a function of shear crack width in RC beams

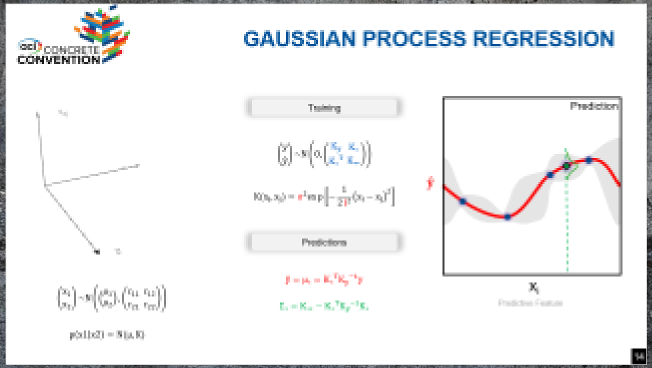
AGENDA

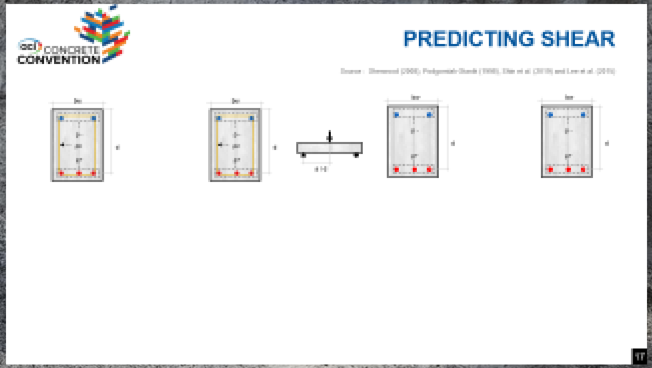

EXPERIMENTAL DATA
122
100
46
Number of specimens:


GAUSSIAN PROCESS REGRESSION
Training
Predictions
Prediction

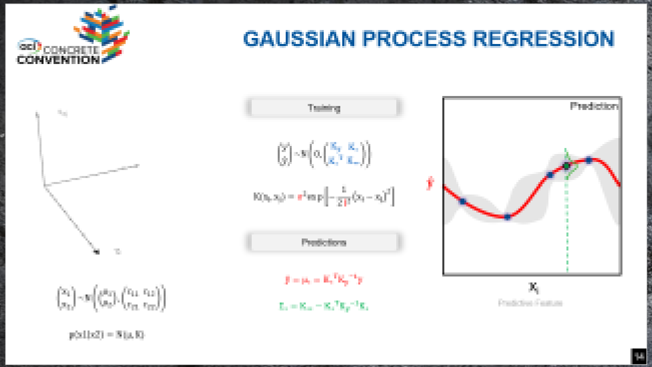
AGENDA

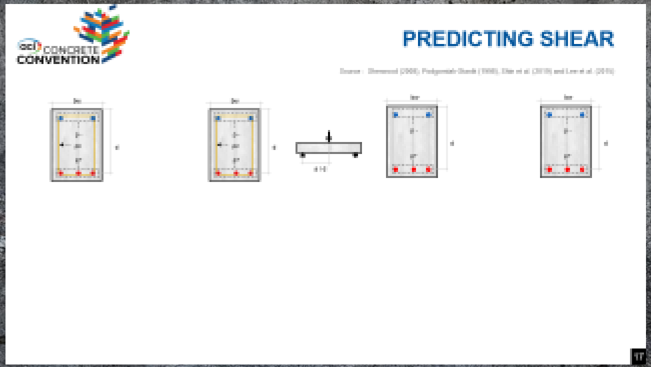

EXPERIMENTAL DATA
122
100
46
Number of specimens:
%V
%K


GAUSSIAN PROCESS REGRESSION
Training
Predictions
Prediction


PREDICTING SHEAR

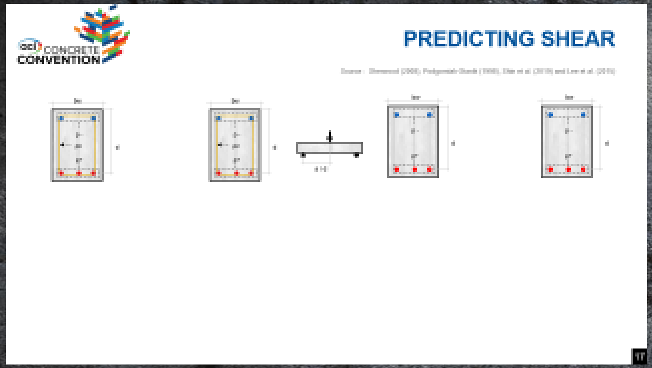
AGENDA


GAUSSIAN PROCESS REGRESSION
Training
Predictions
Prediction

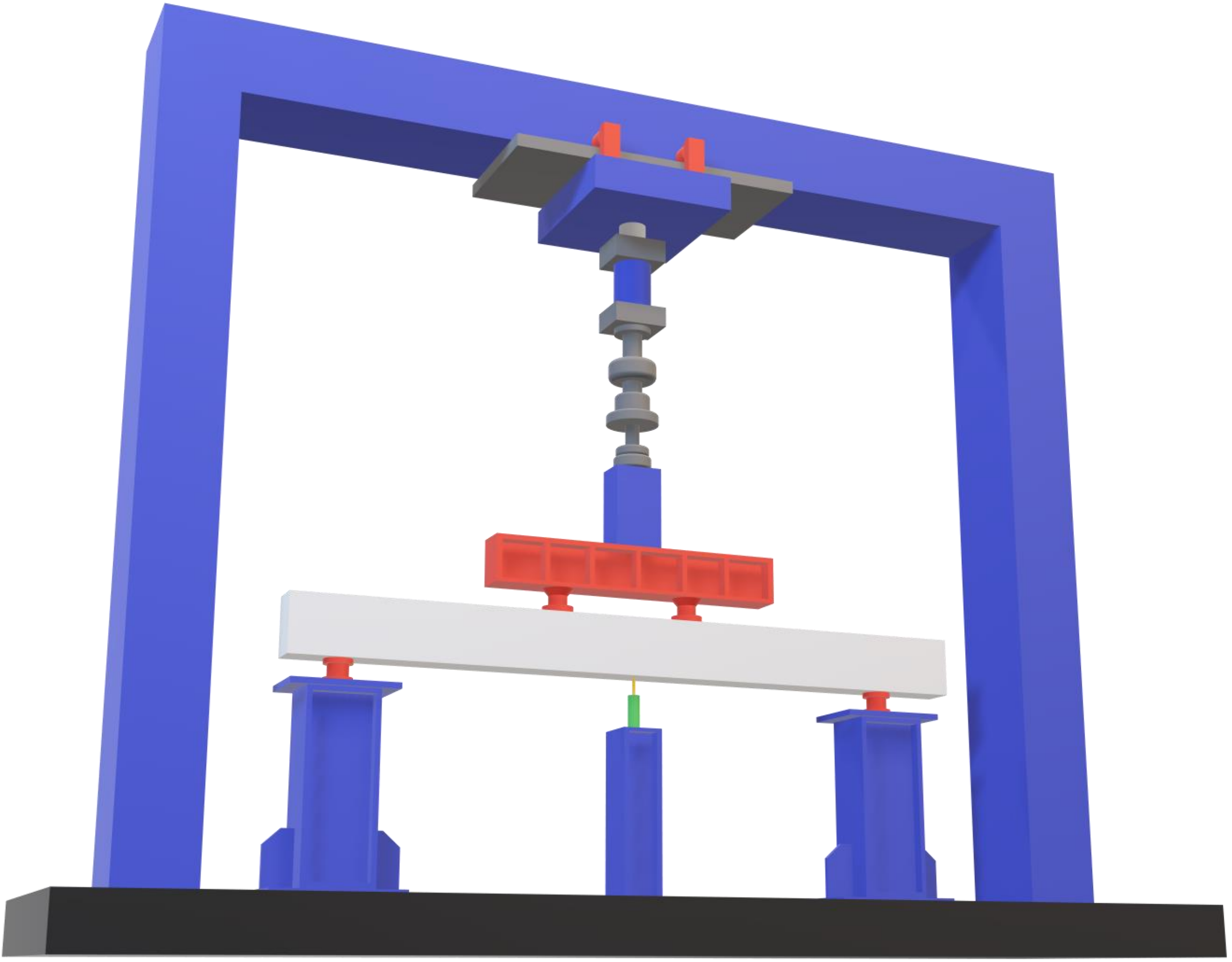

PREDICTING SHEAR


UBEAM

AGENDA

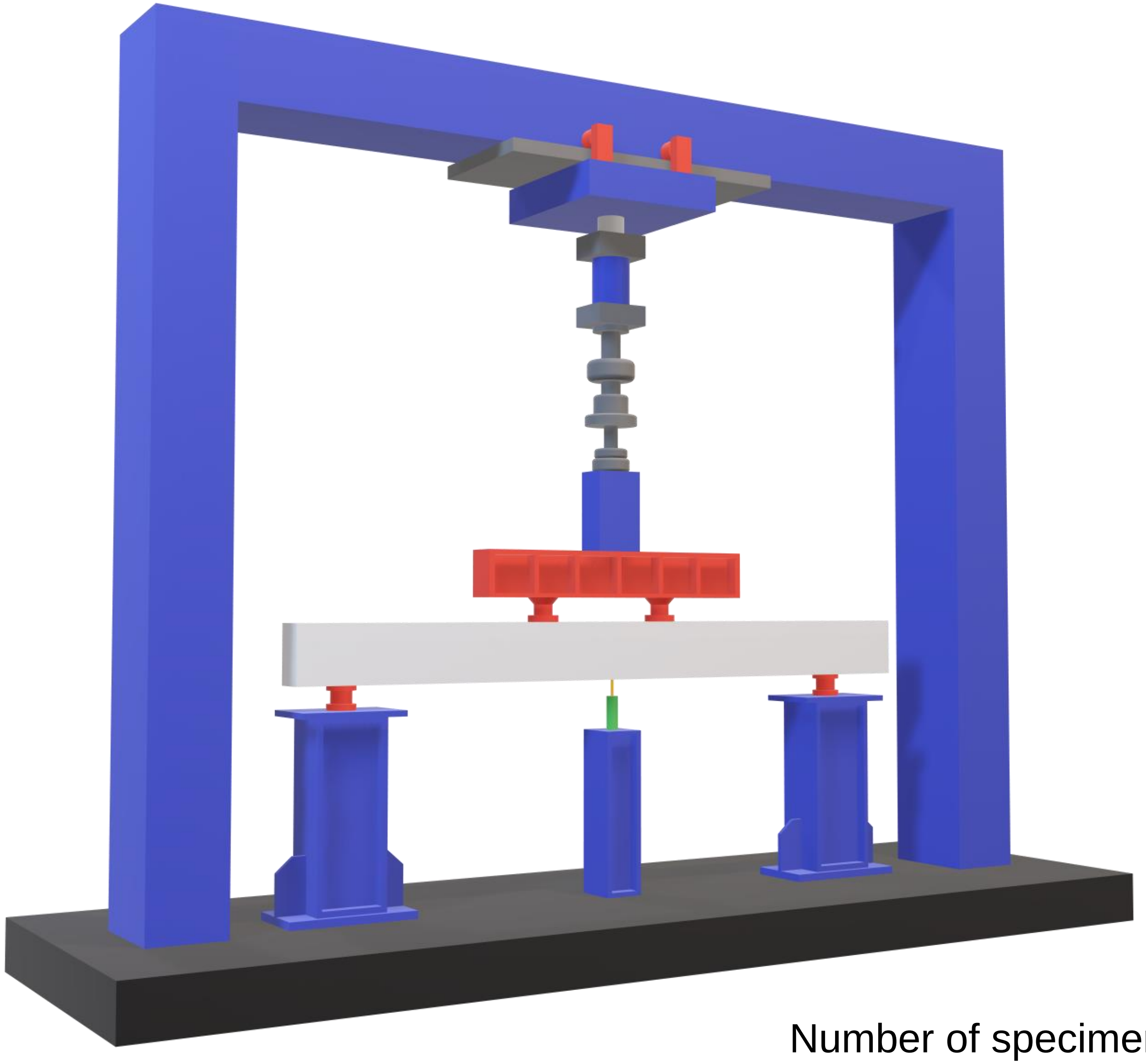


EXPERIMENTAL DATA



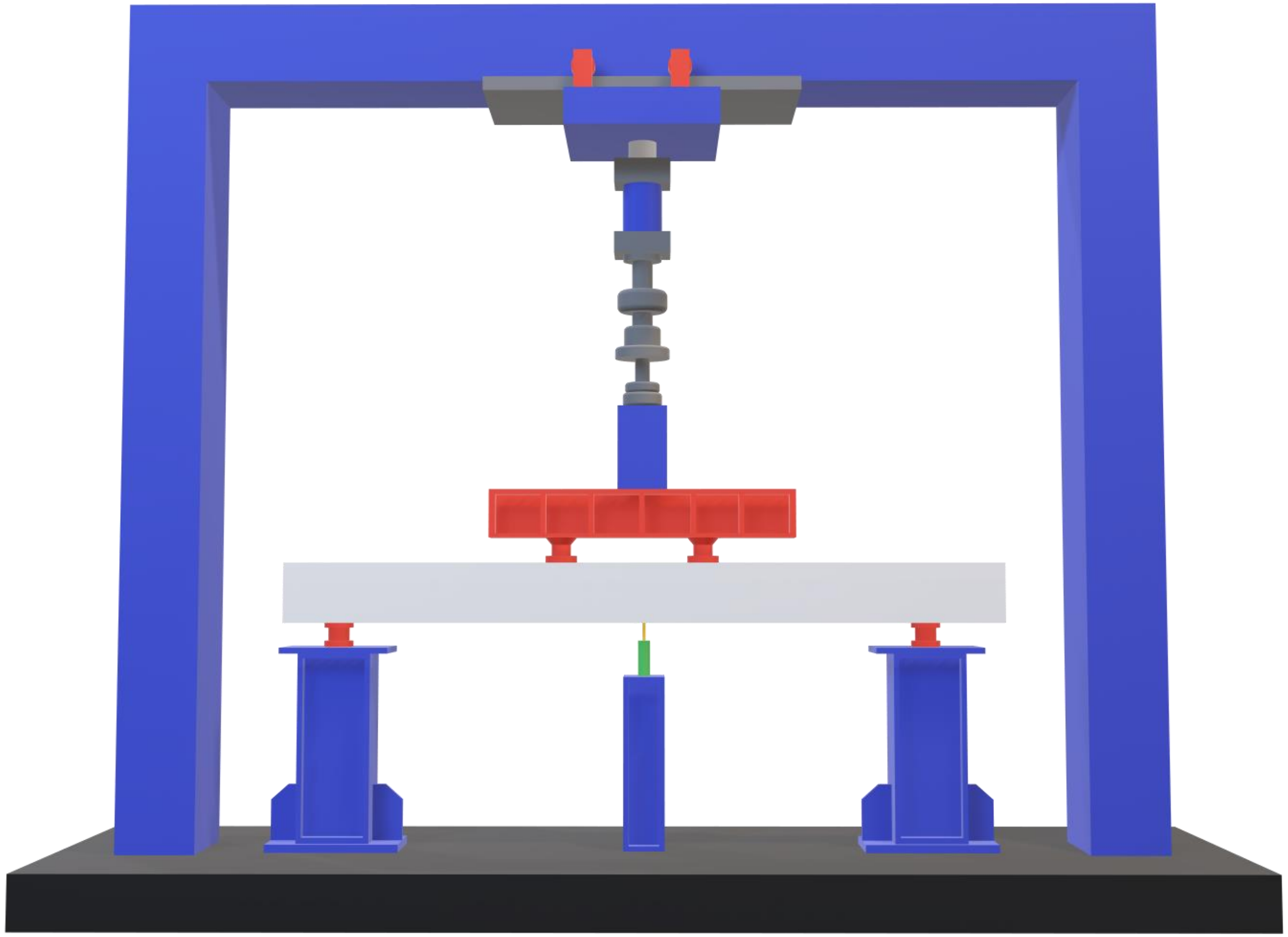
	122	100	46
Number of specimens:	%V	%K	Ɛs/ Ɛy

EXPERIMENTAL DATA



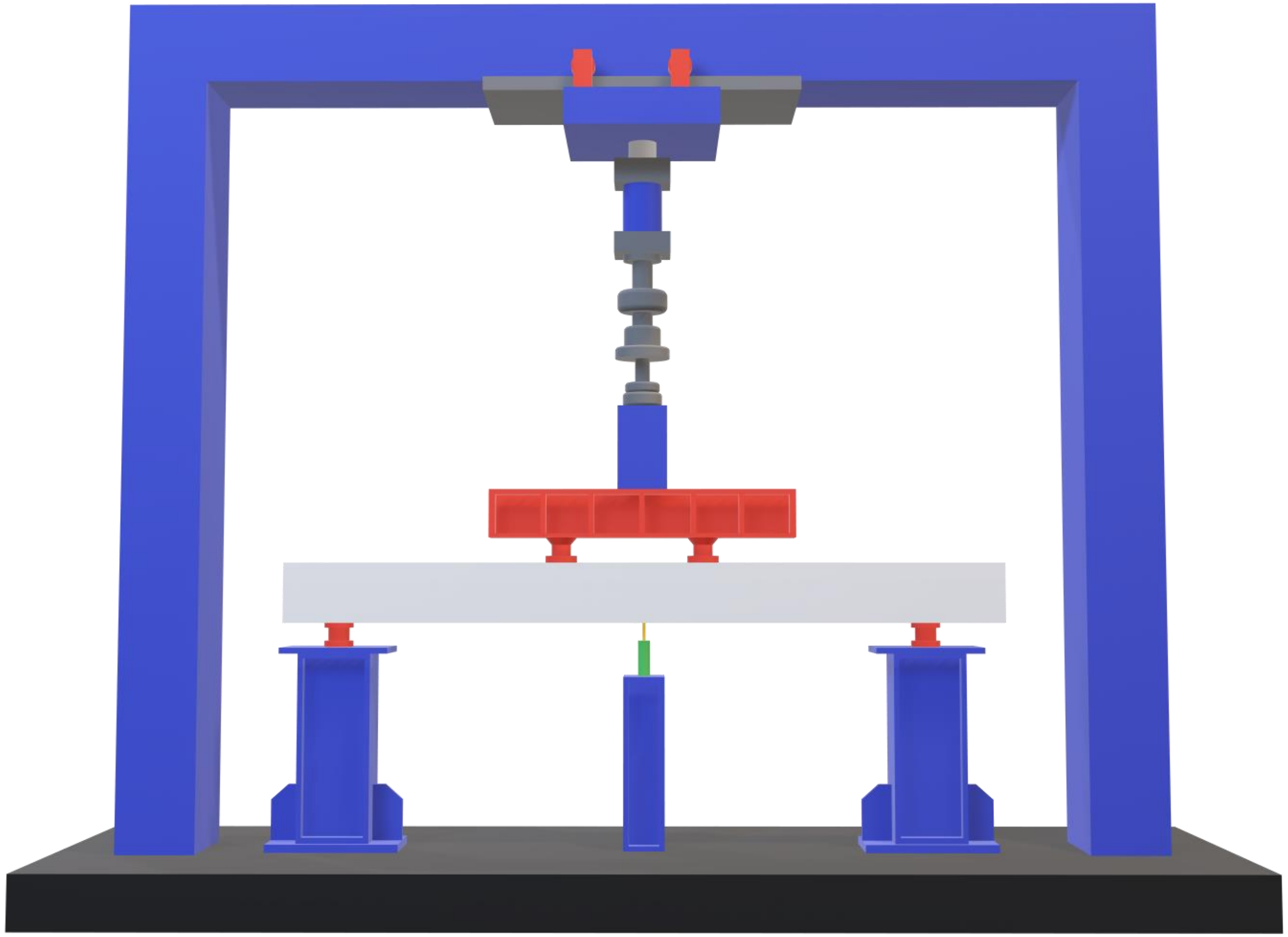
	122	100	46
Number of specimens:	%V	%K	Ɛs/ Ɛy

EXPERIMENTAL DATA



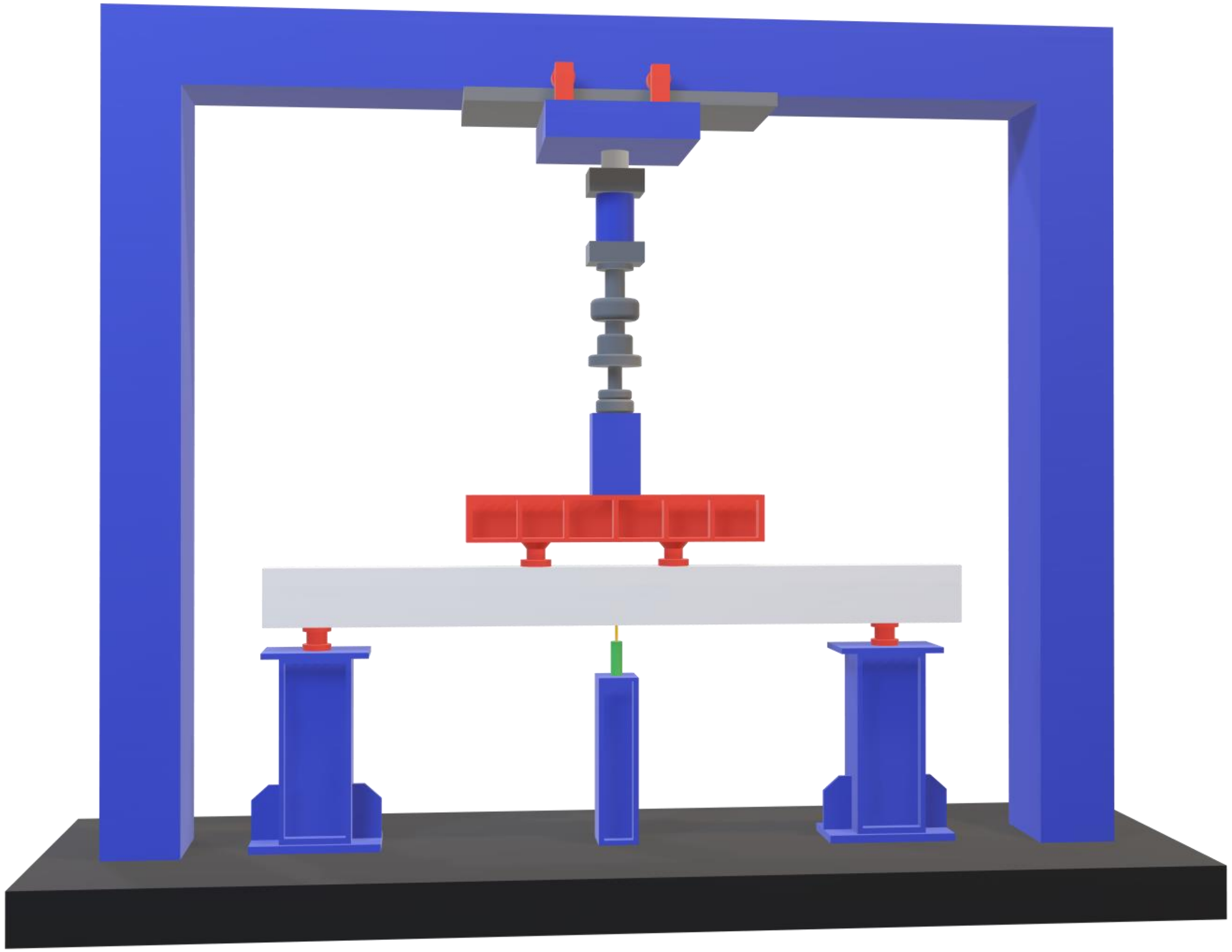
	%V	%K	$\varepsilon_s / \varepsilon_y$
Number of specimens:	122	100	46

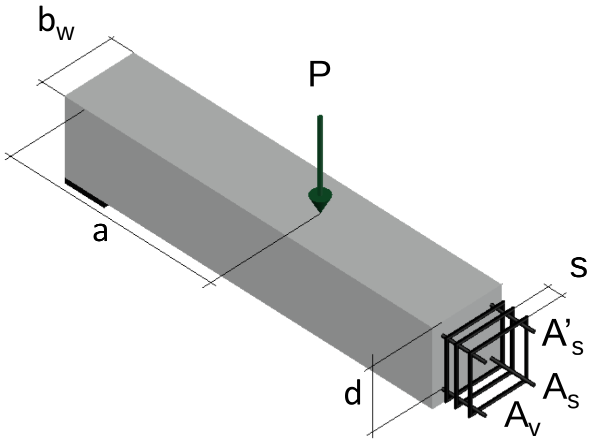
EXPERIMENTAL DATA



	V	%K	Ɛs/ Ɛy
Number of specimens:	122	100	46

EXPERIMENTAL DATA

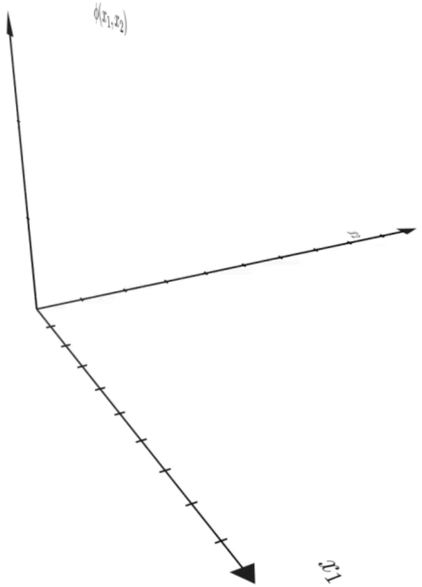




V	%K	Ɛs/ Ɛy
122	100	46

Number of specimens

GAUSSIAN PROCESS REGRESSION



$$\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} \sim N\left(\begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix}, \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix}\right)$$

$$p(x1|x2) = N(\mu, K)$$

Training

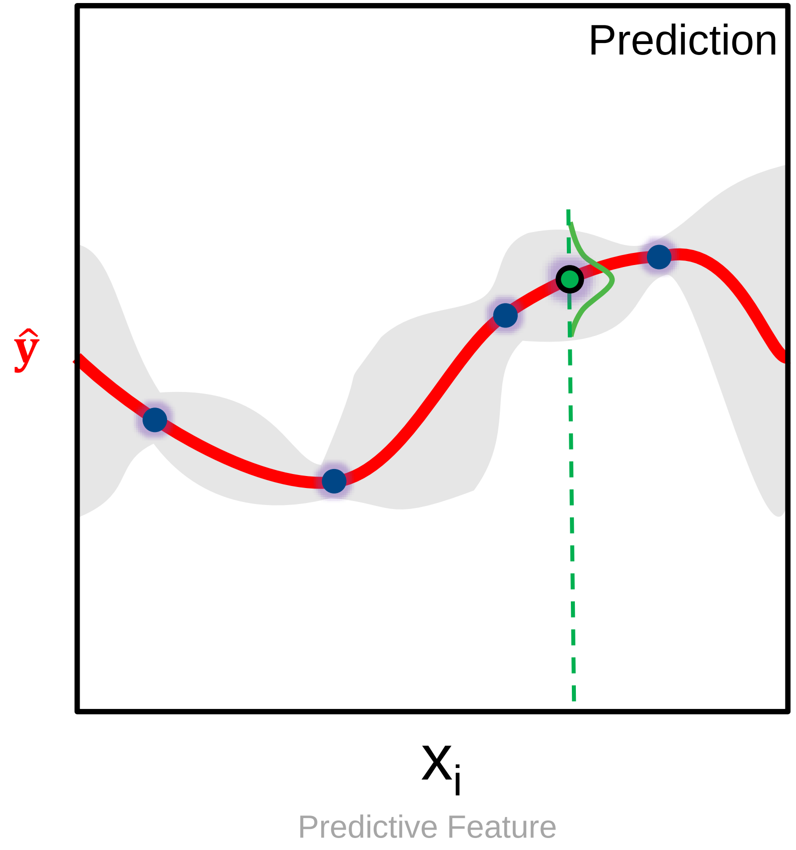
$$\begin{pmatrix} y \\ \hat{y} \end{pmatrix} \sim N\left(0, \begin{pmatrix} K_y & K_* \\ {K_*}^T & K_{**} \end{pmatrix}\right)$$

$$K(x_i, x_j) = \sigma^2 \exp\left[-\frac{1}{2\, l^2}(x_i - x_j)^2\right]$$

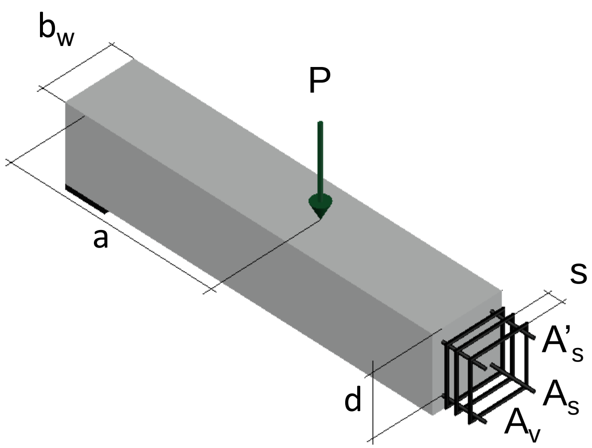
Predictions

$$\hat{y} = \mu_* = {K_*}^T {K_y}^{-1} y$$

$$\Sigma_* = K_{**} - {K_*}^T {K_y}^{-1} K_*$$



MACHINE LEARNING PROCESS

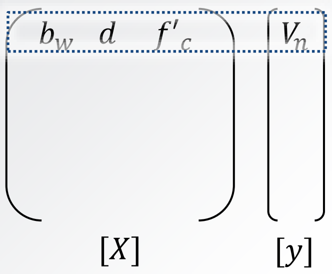


STEP 01

RAW DATA

Predictive Features

Target Feature

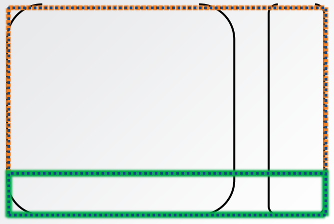


STEP 02

DATA PREPARATION

Training Sets

Validation Sets



STEP 03

TRAINING

Using Training Sets

Gaussian **P**rocess **R**egression

(Murphy 2012)

STEP 04

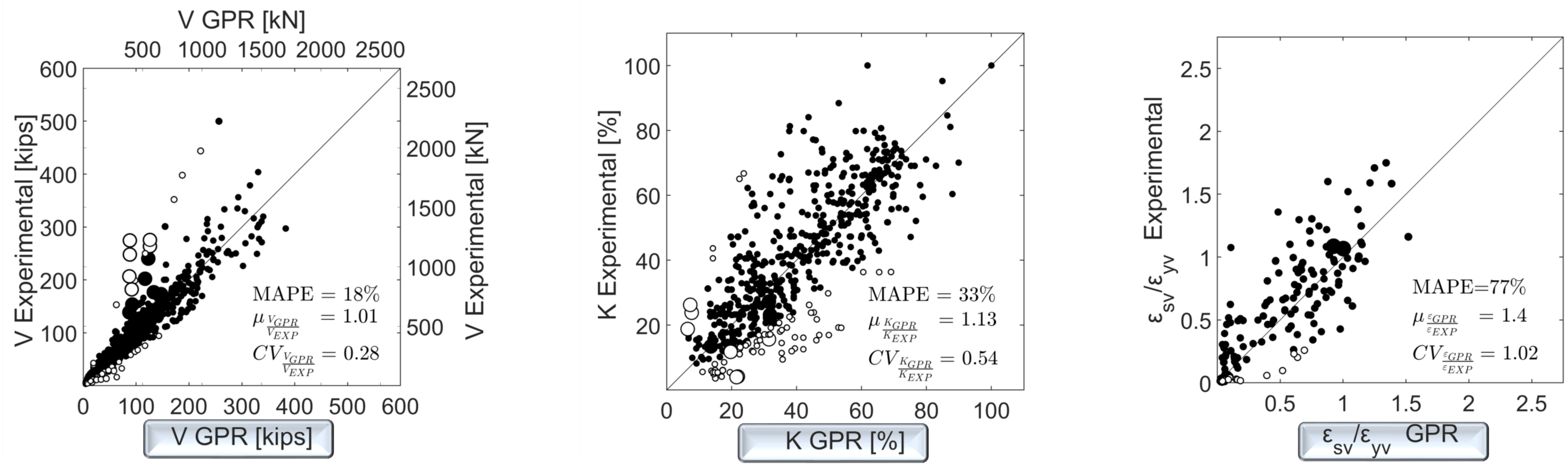
PREDICTIONS

Using Validation Sets

$[\hat{y}] = [V_n]$

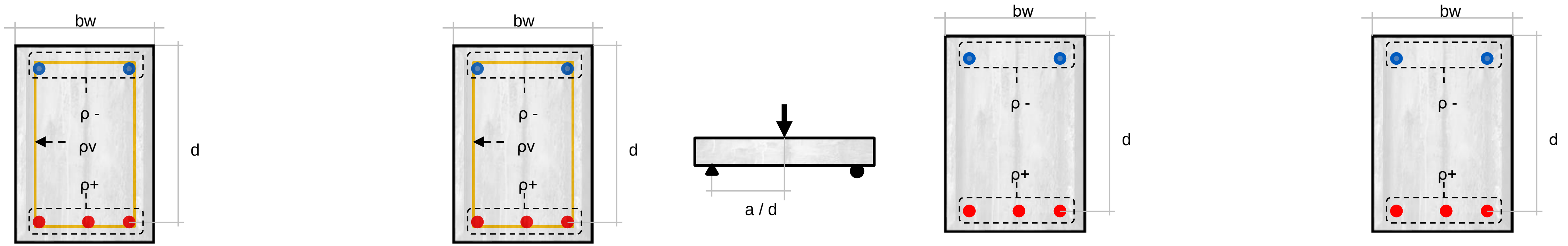
e%

TRAINING ERRORS



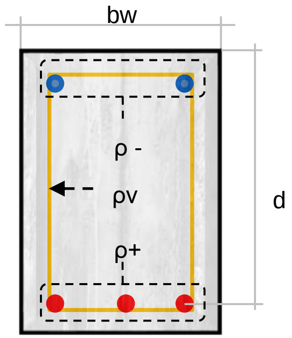
PREDICTING SHEAR

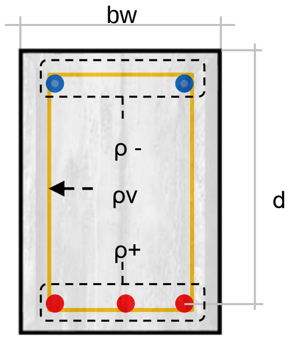
Source : Sherwood (2008), Podgorniak-Stanik (1998), Shin et al. (2019) and Lee et al. (2015)

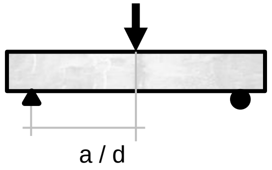


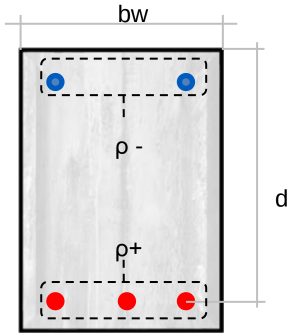
PREDICTING STIFFNESS

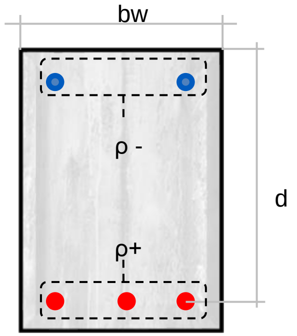
Source : Sherwood (2008), Podgorniak-Stanik (1998), Shin et al. (2019) and Lee et al. (2015)

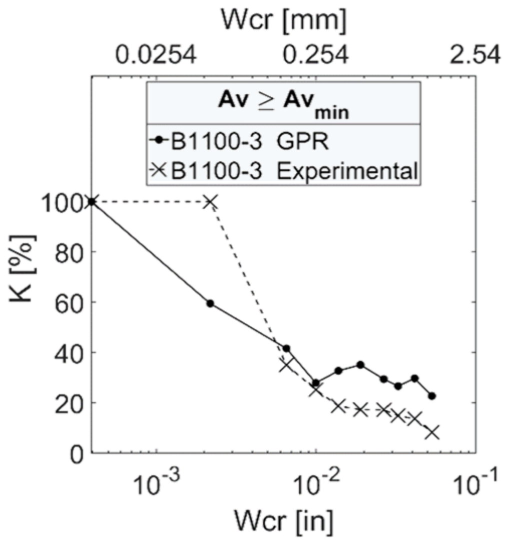


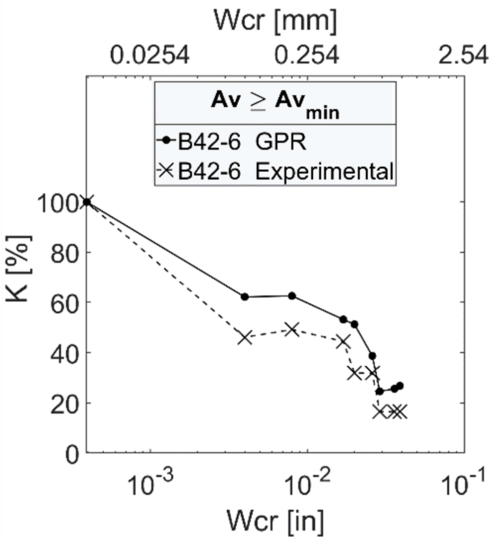


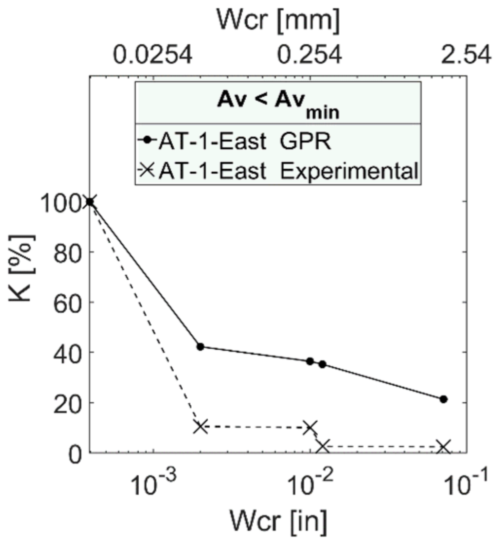


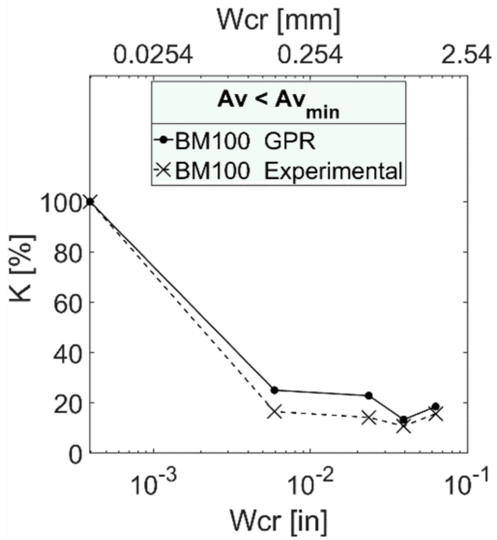






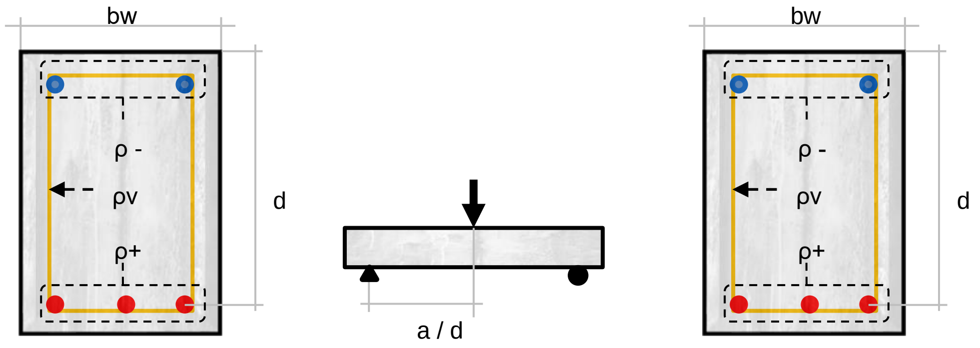


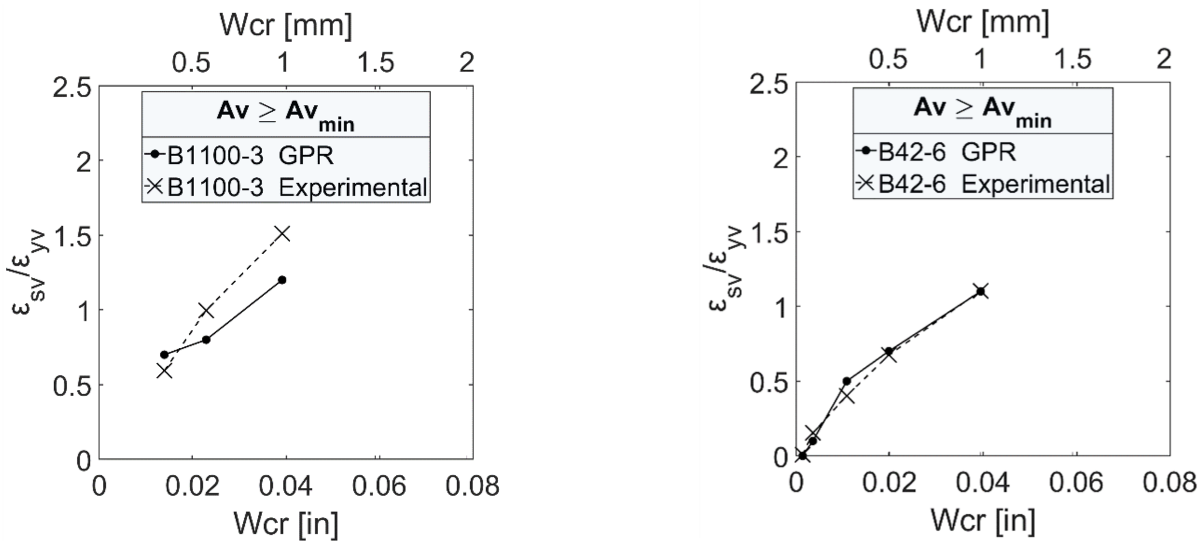




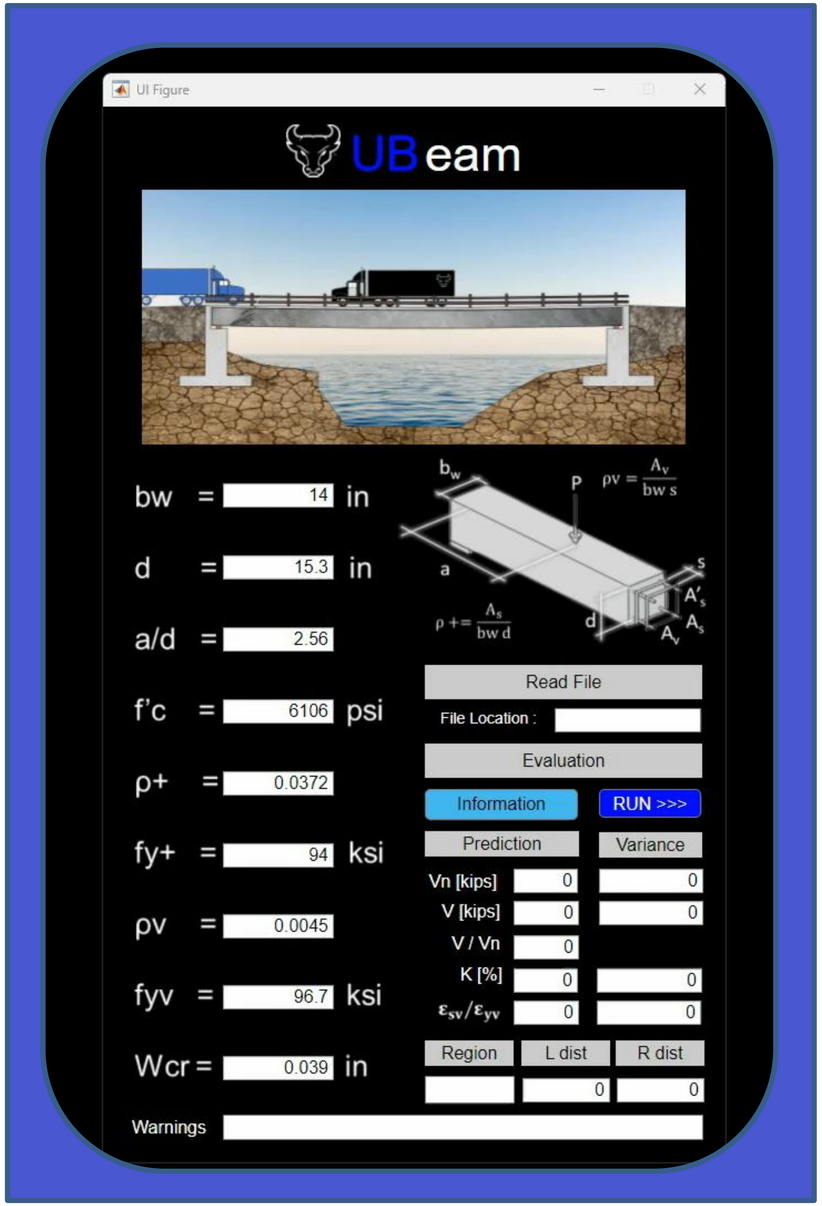
PREDICTING STIRRUP STRAIN

Source : Sherwood (2008), Podgorniak-Stanik (1998), Shin et al. (2019) and Lee et al. (2015)





UBEAM


UI Figure
UBeam
bw = 14 in
d = 15.3 in
a/d = 2.56
f'c = 6106 psi
ρ+ = 0.0372
fy+ = 94 ksi
ρv = 0.0045
fyv = 96.7 ksi
Wcr = 0.039 in
Read File
File Location :
Evaluation
Information
RUN >>>
Prediction
Variance
Vn [kips]
V [kips]
V / Vn
K [%]
Region
L dist
R dist
Warnings

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THANK YOU !

Presenter :

Rodrigo Castillo, Ph.D. candidate — rodrigon@buffalo.edu

Co authors :

Pinar Okumus, Ph.D. — pinaroku@buffalo.edu

Negar Elhami Khorasani, Ph.D. — negarkho@buffalo.edu

Varun Chandola, Ph.D. — chandola@buffalo.edu

Previous publications:

Castillo, R., P. Okumus, N. E. Khorasani; and V. Chandola 2022, "Machine Learning for Shear Strength of Reinforced-Concrete Beams", Structural Journal. 119 (5): 83-94.