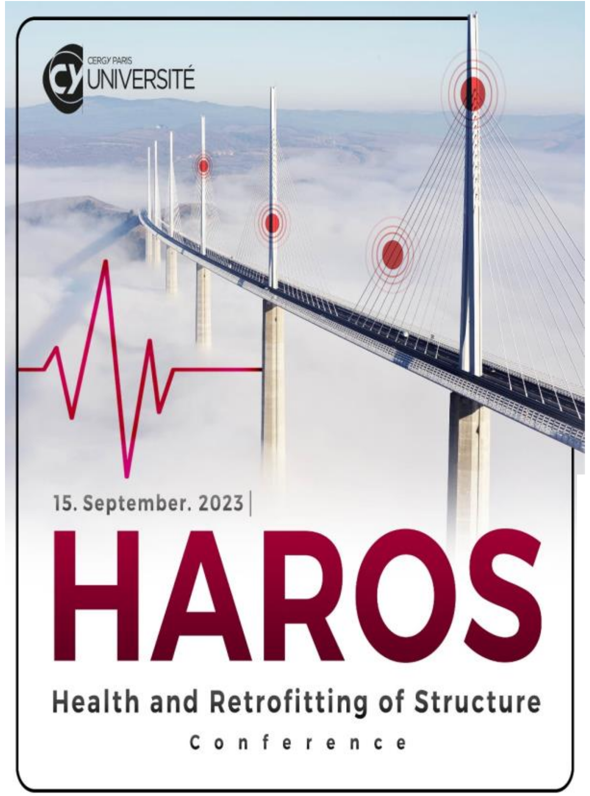

HIESR
المعهد العالي للبحوث والدراسات الزلزالية

Artificial Intelligence in Prediction of Shear Beams Strength

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Artificial intelligence "AI" has big contributions to problem-solving in multiple fields.

The shear strength of the beam is an important factor to have safe buildings.

Calculating of those values is done usually using approximate methods [1].

AI methods proved to give reliable results in multiple fields when used with enough training data [2].

Multiple artificial intelligence and machine learning techniques have been used to predict the shear beam strength.

Several regressors and neural networks have been used

+

A databank established by Reinbeck et al., (2003), for members without transverse reinforcement

+

Kuchma (2000) started a wide-ranging collection of test data on members both with and without transverse reinforcement

→

Evaluation Shear Database

-ESDB-

The shear strength of RC beams without shear reinforcement is of interest to this research in order to :

1- acquire a better understanding of the shear behavior of RC beams.

2- contribution of concrete to the shear strength of RC beams.

THE WIDE DATASET

We have used the collection shear databank **(Evaluation Shear Database -ESDB-)** from [3] to form our dataset.

the dataset had been split into 3 sub-datasets:

1.one for training
2.<u>(70% from databank)</u>

1.one for validating
2.<u>(15% from databank)</u>

1.one for testing
2. <u>(15% from databank)</u>.

The parameters taken into account :

b, h, a/d, ps, fsy, ftk, As2, fsy2, Asw, sw, fyw, Vu

- **Table (1)** gives the abbreviated ESDB with **439 test results** from **67 researchers** .
- It comprises **361 tests satisfying (a/d ≥ 2.9)** and **78 members satisfying (2.40 < a/d < 2.9)** on which the evaluations in this paper were based [3].

Table.1: part of abbreviated Evaluation Shear Database (ESDB) for the data set of shear test on RC-members without transverse reinforcement [3].

Reference Authors	Beam Name	b (mm)	d (mm)	f'_c (MPa)	ρ_l (%)	a/d (-)	V_{test} (kN)	Reference Authors	Beam Name	b (mm)	d (mm)	f'_c (MPa)	ρ_l (%)	a/d (-)	V_{test} (kN)
Ahmad, Kahloo (1986)	A1	127	203	59.3	3.93	4.00	57.8	Kani (1967)	96	156	275	24.0	2.71	3.95	56.3
Ahmad, Kahloo (1986)	A2	127	203	59.3	3.93	3.00	68.9	Kani (1967)	83	156	271	26.1	2.75	3.00	65.0
Ahmad, Kahloo (1986)	A8	127	208	59.3	1.77	3.00	48.9	Kani (1967)	97	152	276	25.9	2.69	2.95	62.5
Ahmad, Kahloo (1986)	B1	127	202	65.5	5.05	4.00	51.3	Kani (1967)	3043	154	1092	25.7	2.71	3.00	166.0
Ahmad, Kahloo (1986)	B2	127	202	65.5	5.05	3.00	69.1	Kani (1967)	56	153	137	25.9	2.65	3.46	28.0
Ahmad, Kahloo (1986)	B7	127	208	65.5	2.25	4.00	46.3	Kani (1967)	58	152	138	25.9	2.65	3.44	28.9
Ahmad, Kahloo (1986)	B8	127	208	65.5	2.25	3.00	46.7	Kani (1967)	60	155	139	25.4	2.60	2.93	39.3
Ahmad, Kahloo (1986)	C1	127	184	62.9	6.62	4.00	54.3	Kani (1967)	91	154	269	26.1	2.70	6.06	51.0
Ahmad, Kahloo (1986)	C2	127	184	62.9	6.62	3.00	75.6	Kani (1967)	92	152	270	26.1	2.73	7.03	45.9
Ahmad, Kahloo (1986)	C7	127	207	62.9	3.28	4.00	45.5	Krefeld, Thurston (1966)	11A2	152	314	28.7	3.42	2.91	73.4
Ahmad, Kahloo (1986)	C8	127	207	62.9	3.28	3.00	44.6	Krefeld, Thurston (1966)	12A2	152	238	28.6	4.51	3.85	64.1
Aster, Koch (1974)	2	1000	250	25.7	0.64	3.68	216.3	Krefeld, Thurston (1966)	18A2	152	316	18.3	2.64	2.89	63.2
Aster, Koch (1974)	3	1000	250	26.0	0.91	3.68	220.7	Krefeld, Thurston (1966)	18B2	152	316	18.9	2.64	2.89	72.1
Aster, Koch (1974)	8	1000	500	29.5	0.63	5.50	280.6	Krefeld, Thurston (1966)	18C2	152	316	21.5	2.64	2.89	73.4
Aster, Koch (1974)	9	1000	500	18.9	0.63	5.50	254.1	Krefeld, Thurston (1966)	18D2	152	316	21.0	2.64	2.89	60.1
Aster, Koch (1974)	10	1000	500	19.0	0.63	5.50	255.1	Krefeld, Thurston (1966)	16A2	152	240	21.1	1.74	3.81	41.8
Aster, Koch (1974)	11	1000	500	23.3	0.46	3.65	261.0	Krefeld, Thurston (1966)	17A2	152	243	20.9	2.14	3.77	44.1
Aster, Koch (1974)	12	1000	500	26.0	0.65	3.65	323.7	Krefeld, Thurston (1966)	3AC	152	256	19.8	2.03	4.77	44.1
Aster, Koch (1974)	16	1000	750	28.8	0.42	3.67	392.4	Krefeld, Thurston (1966)	3CC	152	256	19.5	2.03	5.96	35.6
Aster, Koch (1974)	17	1000	750	27.3	0.42	3.67	349.2	Krefeld, Thurston (1966)	3AAC	152	256	32.8	2.03	3.58	55.6
Bhal (1968)	B1	240	300	22.5	1.26	3.00	71.5	Krefeld, Thurston (1966)	4AAC	152	254	27.7	2.66	3.60	57.9
Bhal (1968)	B2	240	600	28.8	1.26	3.00	119.5	Krefeld, Thurston (1966)	5AAC	152	252	31.2	3.31	3.62	57.0
Bhal (1968)	B3	240	900	26.7	1.26	3.00	165.0	Krefeld, Thurston (1966)	6AAC	152	250	32.7	4.35	3.65	60.1
Bhal (1968)	B4	240	1200	24.5	1.26	3.00	180.0	Krefeld, Thurston (1966)	3AC	152	256	30.3	2.03	4.77	53.4
Bhal (1968)	B5	240	600	25.8	0.63	3.00	106.0	Krefeld, Thurston (1966)	4AC	152	254	29.0	2.66	4.80	53.8
Bhal (1968)	B6	240	600	24.0	0.63	3.00	114.0	Krefeld, Thurston (1966)	5AC	152	252	31.2	3.31	4.83	54.3
Bhal (1968)	B7	240	900	26.5	0.63	3.00	137.5	Krefeld, Thurston (1966)	6AC	152	250	32.4	4.35	4.87	59.2
Bhal (1968)	B8	240	900	26.9	0.63	3.00	125.0	Krefeld, Thurston (1966)	4CC	152	254	36.5	2.66	6.00	52.5
Bresler, Scordelis (1963)	0A-1	310	461	21.4	1.81	3.97	166.9	Krefeld, Thurston (1966)	5CC	152	252	35.6	3.31	6.04	57.4
Bresler, Scordelis (1963)	0A-2	305	466	23.3	2.27	4.91	178.0	Krefeld, Thurston (1966)	6CC	152	250	36.5	4.35	6.09	63.2
Bresler, Scordelis (1963)	0A-3	307	462	35.9	2.73	6.93	189.1	Krefeld, Thurston (1966)	C	203	483	15.9	1.57	3.16	84.6
Chana (1981)	2.1	203	356	37.0	1.74	3.00	96.0	Krefeld, Thurston (1966)	OCA	152	254	33.9	2.66	6.00	48.5
Chana (1981)	2.2	203	356	31.2	1.74	3.00	87.4	Krefeld, Thurston (1966)	OCB	152	254	33.9	2.66	6.00	52.5
Chana (1981)	2.3	203	356	33.9	1.74	3.00	99.4	Krefeld, Thurston (1966)	OCA	254	456	36.4	2.20	4.01	146.9
Cossio, Siess (1960)	L-2A	152	252	34.9	3.35	3.02	80.1	Krefeld, Thurston (1966)	OCB	254	456	36.4	2.20	4.01	133.5
Cossio, Siess (1960)	L-3	152	252	26.6	3.35	4.02	53.4	Collins, Kuchma (1997)	B100	300	925	34.2	1.01	2.92	225.0
Cossio, Siess (1960)	L-4	152	252	24.5	3.35	5.02	51.2	Collins, Kuchma (1997)	B100H	300	925	93.1	1.01	2.92	193.0
Cossio, Siess (1960)	L-5	152	252	26.5	3.35	6.03	51.0	Collins, Kuchma (1997)	B100B	300	925	37.1	1.01	2.92	204.0

Cossio, Siess (1960)	A2	152	254	29.9	0.98	3.00	41.8	Collins, Kuchma (1997)	B100L	300	925	37.1	1.01	2.92	223.0
Cossio, Siess (1960)	A3	152	254	18.5	0.98	4.00	34.3	Podgorniak-Stanik (1998)	BRL100	300	925	89.3	0.50	2.92	164.1
Cossio, Siess (1960)	A-12	152	254	25.4	3.33	3.00	59.0	Podgorniak-Stanik (1998)	BN100	300	925	35.2	0.76	2.92	192.1
Cossio, Siess (1960)	A-13	152	254	21.0	3.33	4.00	46.9	Podgorniak-Stanik (1998)	BH100	300	925	94.1	0.76	2.92	193.1
Cossio, Siess (1960)	A-14	152	254	26.1	3.33	5.00	54.7	Podgorniak-Stanik (1998)	BN50	300	450	35.2	0.81	3.00	131.9
Elzanaty, Nilson, Slate (1986)	F1	178	272	62.2	1.20	4.00	58.6	Podgorniak-Stanik (1998)	BH50	300	450	94.1	0.81	3.00	131.9
Elzanaty, Nilson, Slate (1986)	F2	178	270	75.3	2.50	4.00	67.0	Podgorniak-Stanik (1998)	BN25	300	225	35.2	0.89	3.00	73.0
Elzanaty, Nilson, Slate (1986)	F10	178	268	62.2	3.30	4.00	78.0	Podgorniak-Stanik (1998)	BN12	300	110	35.2	0.91	3.07	40.1
Elzanaty, Nilson, Slate (1986)	F9	178	268	75.3	1.60	4.00	64.0	Laupa, Siess (1953)	S2	152	269	25.6	2.08	4.54	42.5
Elzanaty, Nilson, Slate (1986)	F15	178	268	60.3	2.50	4.00	68.0	Laupa, Siess (1953)	S3	152	265	30.7	2.52	4.60	53.1
Elzanaty, Nilson, Slate (1986)	F6	178	267	62.2	2.50	6.00	62.0	Laupa, Siess (1953)	S4	152	263	29.3	3.21	4.61	55.6
Elzanaty, Nilson, Slate (1986)	F11	178	272	19.7	1.20	4.00	45.5	Laupa, Siess (1953)	S5	152	262	28.4	4.11	4.65	49.8
Elzanaty, Nilson, Slate (1986)	F12	178	269	19.7	2.50	4.00	54.6	Laupa, Siess (1953)	S11	152	267	14.0	1.90	4.56	33.8
Elzanaty, Nilson, Slate (1986)	F8	178	273	38.0	1.00	4.00	46.7	Laupa, Siess (1953)	S13	152	262	24.9	4.11	4.56	49.8
Elzanaty, Nilson, Slate (1986)	F13	178	272	38.0	1.20	4.00	47.0	Leonhardt, Walther (1962)	P8	502	148	24.2	0.91	3.31	92.8
Elzanaty, Nilson, Slate (1986)	F14	178	269	38.0	2.50	4.00	64.6	Leonhardt, Walther (1962)	P9	500	146	24.2	1.86	3.36	107.8
Feldman, Siess (1955)	L-2A	152	252	34.9	3.35	3.02	80.1	Leonhardt, Walther (1962)	51	190	270	28.0	2.07	3.00	60.3
Feldman, Siess (1955)	L-3	152	252	26.6	3.35	4.02	53.4	Leonhardt, Walther (1962)	5r	190	270	28.0	2.07	3.00	76.5
Feldman, Siess (1955)	L-4	152	252	24.5	3.35	5.03	51.2	Leonhardt, Walther (1962)	61	190	270	28.0	2.07	4.07	60.8
Feldman, Siess (1955)	L-5	152	252	26.5	3.35	6.04	51.2	Leonhardt, Walther (1962)	6r	190	270	28.0	2.07	4.07	68.2
Grimm (1997)	s1.1	300	153	85.6	1.34	3.73	70.1	Leonhardt, Walther (1962)	7-1	190	270	29.4	2.07	5.00	62.3
Grimm (1997)	s1.2	300	152	86.6	2.21	3.75	75.8	Leonhardt, Walther (1962)	7-2	190	270	29.4	2.07	5.00	68.2
Grimm (1997)	s1.3	300	146	89.0	4.22	3.90	98.6	Leonhardt, Walther (1962)	8-1	190	270	29.4	2.07	6.00	65.7
Grimm (1997)	s2.2	300	348	86.7	1.88	3.53	187.1	Leonhardt, Walther (1962)	8-2	190	270	29.4	2.07	6.00	65.7
Grimm (1997)	s2.3	300	348	89.0	0.94	3.53	123.1	Leonhardt, Walther (1962)	D2/1	100	140	35.4	1.62	3.00	21.2
Grimm (1997)	s2.4	300	328	89.4	3.76	3.75	229.8	Leonhardt, Walther (1962)	D2/2	100	140	35.4	1.62	3.00	23.3
Grimm (1997)	s3.2	300	718	89.0	1.72	3.66	259.1	Leonhardt, Walther (1962)	D3/1	150	210	36.6	1.62	3.00	46.4
Grimm (1997)	s3.3	300	746	89.7	0.83	3.53	192.8	Leonhardt, Walther (1962)	D3/2l	150	210	36.6	1.62	3.00	41.2
Grimm (1997)	s3.4	300	690	89.4	3.57	3.81	379.0	Leonhardt, Walther (1962)	D3/2r	150	210	36.6	1.62	3.00	44.5
Hallgren (1994)	B90SB13-2-86	163	192	81.9	2.17	3.65	82.5	Leonhardt, Walther (1962)	D4/1	200	280	33.6	1.62	3.00	74.1
Hallgren (1994)	B90SB14-2-86	158	194	81.9	2.21	3.61	76.5	Leonhardt, Walther (1962)	D4/2l	200	280	33.6	1.62	3.00	74.1
Hallgren (1994)	B90SB22-2-85	158	193	80.4	2.22	3.63	75.5	Leonhardt, Walther (1962)	D4/2r	200	280	33.6	1.62	3.00	68.7
Hallgren (1994)	B91SC2-2-62	155	196	58.7	2.23	3.57	69.5	Leonhardt, Walther (1962)	C1	100	150	37.2	1.34	3.00	21.6
Hallgren (1994)	B91SC4-2-69	156	195	65.6	2.23	3.59	74.0	Leonhardt, Walther (1962)	C2	150	300	37.2	1.34	3.00	64.8
Hallgren (1994)	B90SB17-2-45	157	191	42.7	2.26	3.66	59.0	Leonhardt, Walther (1962)	C3	200	450	37.2	1.34	3.00	99.1
Hallgren (1994)	B90SB18-2-45	155	194	42.7	2.25	3.61	63.0	Leonhardt, Walther (1962)	C4	225	600	37.2	1.34	3.00	147.2
Hallgren (1994)	B90SB21-2-85	155	194	80.4	2.25	3.61	69.0	Marti, Pralong, Th? limann (1977)	PS11	400	144	28.1	1.60	4.44	90.0
Hallgren (1994)	B91SC1-2-62	156	193	58.7	2.25	3.63	71.0	Mathey, Watstein (1963)	IIIa-17	203	403	27.8	2.55	3.78	90.0
Hallgren (1994)	B91SD1-4-61	156	194	57.8	3.98	3.61	88.5	Mathey, Watstein (1963)	IIIa-18	203	403	23.9	2.55	3.78	82.5
Hallgren (1994)	B91SD2-4-61	156	195	57.8	3.96	3.59	90.0	Mathey, Watstein (1963)	Va-19	203	403	22.3	0.93	3.78	64.7
Hallgren (1994)	B91SD3-4-66	156	195	62.4	3.96	3.59	81.5	Mathey, Watstein (1963)	Va-20	203	403	24.3	0.93	3.78	67.4
Hallgren (1994)	B91SD4-4-66	155	195	62.4	3.99	3.59	79.0	Mathey, Watstein (1963)	VIa-24	203	403	25.0	0.47	3.78	55.7
Hallgren (1994)	B91SD5-4-58	156	196	55.4	3.94	3.57	78.0	Mathey, Watstein (1963)	VIa-25	203	403	24.5	0.47	3.78	51.0
Hallgren (1994)	B91SD6-4-58	150	196	55.4	4.10	3.57	82.5	Morrow, Viest (1957)	B56B2	305	368	14.0	1.89	3.86	102.2

- **Table (2)** is a revised and more extended version with **398 tests** for considering the size effect of members without transverse reinforcement [3].

Table.2: part of Slightly modified Evaluation Shear Database (ESDB) for the data set of shear test on RC-members without transverse reinforcement [3].

	Autor	Vers.Nr.	shape	Geometrie									Concrete												Reinforcement						Load	
				b		b_w		h		d		a/d	$Ø_s$		control	f_{1c}		f_{pc}		control	$f_{ct,test}$		$f_{ct,cal}$		Asl		ρ_l	ρ_{lw}	f_y		Vct	
				b_in	b	bw_in	bw	h_in	h	d_in	d	kap	diaa_in	diaa	specimen	f1c_psi	f1c	fpc_psi	fpc	specimen	flctest_psi	flctest	flctcal_psi	flct,cal	Asl_in	Asl	rhol	rholw	fy_ksi	fy	vct_kips	vct
Nr.	Autor	Vers.Nr.	R / T / I	in	mm	in	mm	in	mm	in	mm	-	in	mm		psi	MPa	psi	MPa		psi	MPa	psi	MPa	in²	mm²	%	%	ksi	MPa	kips	kN
1	Adebar, Collins (1996)	ST1	R	14,17	360	14,17	360	12,20	310	10,94	278	2,88	0,75	19,0	cyl	7232	49,9	7612,5	52,5	sp	561	3,870	582	4,016	2,43	1570	1,57	1,57	77,7	536	28,67	127,526
2	Adebar, Collins (1996)	ST2	R	14,17	360	14,17	360	12,20	310	10,94	278	2,88	0,75	19,0	cyl	7232	49,9	7612,5	52,5	sp	561	3,870	582	4,016	2,43	1570	1,57	1,57	77,7	536	26,68	118,670
3	Adebar, Collins (1996)	ST3	R	11,42	290	11,42	290	12,20	310	10,94	278	2,88	0,75	19,0	cyl	6791	46,8	7148,5	49,3	sp	587	4,050	556	3,838	2,43	1570	1,95	1,95	77,7	536	24,21	107,723
4	Adebar, Collins (1996)	ST8	R	11,42	290	11,42	290	12,20	310	10,94	278	2,88	0,75	19,0	cyl	6364	43,9	6699,0	46,2	sp	561	3,870	531	3,661	2,43	1570	1,95	1,95	77,7	536	18,12	80,614
5	Adebar, Collins (1996)	ST16	R	11,42	290	11,42	290	8,27	210	7,01	178	4,49	0,75	19,0	cyl	7094	48,9	7467,5	51,5	sp	483	3,330	574	3,961	2,43	1570	3,04	3,04	77,7	536	16,89	75,110
6	Adebar, Collins (1996)	ST23	R	11,42	290	11,42	290	12,20	310	10,94	278	2,88	0,75	19,0	cyl	8113	56,0	8540,5	58,9	sp	731	5,040	614	4,238	1,240	800	0,99	0,99	77,7	536	20,21	89,888
7	Ahmad, Kahloo (1986)	A1	R	5,00	127	5,00	127	10,00	254	8,00	203	4,00	0,50	12,7	cy3	8595	59,3	9047,2	62,4				627	4,326	1,57	1013	3,93	3,93	60,0	414	13,00	57,824
8	Ahmad, Kahloo (1986)	A2	R	5,00	127	5,00	127	10,00	254	8,00	203	3,00	0,50	12,7	cy3	8595	59,3	9047,2	62,4				627	4,326	1,57	1013	3,93	3,93	60,0	414	15,50	68,944
9	Ahmad, Kahloo (1986)	A3	R	5,00	127	5,00	127	10,00	254	8,00	203	2,70	0,50	12,7	cy3	8595	59,3	9047,2	62,4				627	4,326	1,57	1013	3,93	3,93	60,0	414	15,50	68,944
10	Ahmad, Kahloo (1986)	A8	R	5,00	127	5,00	127	10,00	254	8,19	208	3,00	0,50	12,7	cy3	8595	59,3	9047,2	62,4				627	4,326	0,72	467	1,77	1,77	60,0	414	11,00	48,928
11	Ahmad, Kahloo (1986)	B1	R	5,00	127	5,00	127	10,00	254	7,94	202	4,00	0,50	12,7	cy3	9464	65,3	9962,3	68,7				649	4,476	2,00	1289	5,03	5,03	60,0	414	11,51	51,210
12	Ahmad, Kahloo (1986)	B2	R	5,00	127	5,00	127	10,00	254	7,94	202	3,00	0,50	12,7	cy3	9464	65,3	9962,3	68,7				649	4,476	2,00	1289	5,03	5,03	60,0	414	15,50	68,944
13	Ahmad, Kahloo (1986)	B3	R	5,00	127	5,00	127	10,00	254	7,94	202	2,70	0,50	12,7	cy3	9464	65,3	9962,3	68,7				649	4,476	2,00	1289	5,03	5,03	60,0	414	22,50	100,080
14	Ahmad, Kahloo (1986)	B7	R	5,00	127	5,00	127	10,00	254	8,19	208	4,00	0,50	12,7	cy3	9464	65,3	9962,3	68,7				649	4,476	0,92	594	2,25	2,25	60,0	414	10,00	44,480
15	Ahmad, Kahloo (1986)	B8	R	5,00	127	5,00	127	10,00	254	8,19	208	3,00	0,50	12,7	cy3	9464	65,3	9962,3	68,7				649	4,476	0,92	594	2,25	2,25	60,0	414	10,50	46,704
16	Ahmad, Kahloo (1986)	B9	R	5,00	127	5,00	127	10,00	254	8,19	208	2,70	0,50	12,7	cy3	9464	65,3	9962,3	68,7				649	4,476	0,92	594	2,25	2,25	60,0	414	18,00	80,064
17	Ahmad, Kahloo (1986)	C1	R	5,00	127	5,00	127	10,00	254	7,25	184	4,00	0,50	12,7	cy3	9088	62,7	9566,0	66,0				640	4,412	2,41	1552	6,64	6,64	60,0	414	12,20	54,266
18	Ahmad, Kahloo (1986)	C2	R	5,00	127	5,00	127	10,00	254	7,25	184	3,00	0,50	12,7	cy3	9088	62,7	9566,0	66,0				640	4,412	2,41	1552	6,64	6,64	60,0	414	17,00	75,616
19	Ahmad, Kahloo (1986)	C3	R	5,00	127	5,00	127	10,00	254	7,25	184	2,70	0,50	12,7	cy3	9088	62,7	9566,0	66,0				640	4,412	2,41	1552	6,64	6,64	60,0	414	15,50	68,944
20	Ahmad, Kahloo (1986)	C7	R	5,00	127	5,00	127	10,00	254	8,13	207	4,00	0,50	12,7	cy3	9088	62,7	9566,0	66,0				640	4,412	1,33	855	3,26	3,26	60,0	414	10,20	45,370
21	Ahmad, Kahloo (1986)	C8	R	5,00	127	5,00	127	10,00	254	8,13	207	3,00	0,50	12,7	cy3	9088	62,7	9566,0	66,0				640	4,412	1,33	855	3,26	3,26	60,0	414	10,00	44,480
22	Ahmad, Kahloo (1986)	C9	R	5,00	127	5,00	127	10,00	254	8,13	207	2,70	0,50	12,7	cy3	9088	62,7	9566,0	66,0				640	4,412	1,33	855	3,26	3,26	60,0	414	10,20	45,370
23	Al-Alusi (1957)	7	T	13,00	330	3,00	76	5,75	146	5,00	127	4,50	0,25	6,4	cyl	3506	24,2	3690,0	25,4	fl	314	2,166	338	2,331	0,39	253	0,60	2,62	53,0	366	3,05	13,550
24	Al-Alusi (1957)	10	T	13,00	330	3,00	76	5,75	146	5,00	127	4,00	0,25	6,4	cyl	3943	27,2	4150,0	28,6	fl	333	2,298	371	2,556	0,39	253	0,60	2,62	53,0	366	3,31	14,718
25	Al-Alusi (1957)	11	T	13,00	330	3,00	76	5,75	146	5,00	127	3,40	0,25	6,4	cyl	3943	27,2	4150,0	28,6	fl	363	2,504	371	2,556	0,39	253	0,60	2,62	53,0	366	3,91	17,405
26	Al-Alusi (1957)	18	T	13,00	330	3,00	76	5,75	146	5,00	127	4,50	0,25	6,4	cyl	3705	25,6	3900,0	26,9	fl	344	2,371	353	2,435	0,39	253	0,60	2,62	53,0	366	3,15	14,018
27	Angelakos, Bentz, Collins (2001)	DB120	R	11,81	300	11,81	300	39,37	1000	36,42	925	2,92	0,39	10,0	cyl	2893	20,0	3045,0	21,0				290	1,997	4,34	2800	1,01	1,01	79,8	550	40,24	179,000
28	Angelakos, Bentz, Collins (2001)	DB130	R	11,81	300	11,81	300	39,37	1000	36,42	925	2,92	0,39	10,0	cyl	4408	30,4	4640,0	32,0				404	2,785	4,34	2800	1,01	1,01	79,8	550	41,59	185,000
29	Angelakos, Bentz, Collins (2001)	DB140	R	11,81	300	11,81	300	39,37	1000	36,42	925	2,92	0,39	10,0	cyl	5235	36,1	5510,0	38,0				460	3,170	4,34	2800	1,01	1,01	79,8	550	40,47	180,000
30	Angelakos, Bentz, Collins (2001)	DB165	R	11,81	300	11,81	300	39,37	1000	36,42	925	2,92	0,39	10,0	cyl	8954	61,8	9425,0	65,0				636	4,389	4,34	2800	1,01	1,01	79,8	550	41,59	185,000
31	Angelakos, Bentz, Collins (2001)	DB180	R	11,81	300	11,81	300	39,37	1000	36,42	925	2,92	0,39	10,0	cyl	11020	76,0	11600,0	80,0				685	4,723	4,34	2800	1,01	1,01	79,8	550	38,67	172,000
32	Angelakos, Bentz, Collins (2001)	DB230	R	11,81	300	11,81	300	39,37	1000	35,24	895	3,02	0,39	10,0	cyl	4408	30,4	4640,0	32,0				404	2,785	8,68	5600	2,09	2,09	79,8	550	57,78	257,000
33	Angelakos, Bentz, Collins (2001)	DBO530	R	11,81	300	11,81	300	39,37	1000	36,42	925	2,92	0,39	10,0	cyl	4408	30,4	4640,0	32,0				404	2,785	2,17	1400	0,50	0,50	79,8	550	37,10	165,000
34	Aster; Koch (1974)	2	R	39,37	1000	39,37	1000	11,06	281	9,84	250	3,68	1,18	30,0	cu2	3708	25,6	3902,9	26,9	fl	350	2,413	353	2,437	2,48	1600	0,64	0,64	80,3	554	48,63	216,310
35	Aster; Koch (1974)	3	R	39,37	1000	39,37	1000	11,36	289	9,84	250	3,68	1,18	30,0	cu2	3764	26,0	3961,9	27,3	fl	393	2,708	357	2,465	3,53	2280	0,91	0,91	77,6	535	49,62	220,730
36	Aster; Koch (1974)	8	R	39,37	1000	39,37	1000	21,42	544	19,69	500	5,50	1,18	30,0	pr1	4282	29,5	4506,9	31,1	fl	427	2,943	395	2,724	4,87	3140	0,63	0,63	77,7	536	63,08	280,570
37	Aster; Koch (1974)	9	R	39,37	1000	39,37	1000	21,42	544	19,69	500	5,50	1,18	30,0	pr1	2745	18,9	2889,8	19,9	fl	248	1,707	277	1,912	4,87	3140	0,63	0,63	77,7	536	57,12	254,080
38	Aster; Koch (1974)	10	R	39,37	1000	39,37	1000	21,42	544	19,69	500	5,50	1,18	30,0	pr1	2760	19,0	2904,8	20,0	fl	239	1,648	278	1,920	4,87	3140	0,63	0,63	77,7	536	57,34	255,060
39	Aster; Koch (1974)	11	R	39,37	1000	39,37	1000	21,20	539	19,69	500	3,65	1,18	30,0	pr1	3385	23,3	3563,6	24,6	fl	307	2,119	329	2,268	3,53	2280	0,46	0,46	77,6	535	58,67	260,950
40	Aster; Koch (1974)	12	R	39,37	1000	39,37	1000	21,26	540	19,69	500	3,65	1,18	30,0	cu2	3764	26,0	3961,9	27,3	fl	393	2,708	357	2,465	5,05	3260	0,65	0,65	77,6	535	72,78	323,730
41	Aster; Koch (1974)	16	R	39,37	1000	39,37	1000	31,26	794	29,53	750	3,67	1,18	30,0	pr1	4182	28,8	4402,1	30,4	fl	350	2,413	388	2,675	4,87	3140	0,42	0,42	77,7	536	88,22	392,400
42	Aster; Koch (1974)	17	R	39,37	1000	39,37	1000	31,26	794	29,53	750	3,67	1,18	30,0	pr1	3954	27,3	4162,5	28,7	fl	358	2,472	371	2,562	4,87	3140	0,42	0,42	77,7	536	78,52	349,240

- To make comparisons between different tests and code equations **table (3)**, it was necessary to convert strength values determined on different control specimens to standardized and unique strength values.

Table.3: Conversion factors of concrete compressive strengths of different specimens.

Specimen strength	Relational equation	Specimen type and size, mm
$f_{c,cyl}$	$f_{1c,cyl} = 0.95\ f_{c,cyl}$	Cylinder ø150 X H300
$f_{c,cube}$	$f_{1c,cube} = 0.75\ f_{c,cube}$	Cube 150 X 150
$f_{c,cyl,100/300}$	$f_{c,cyl} = 1.05\ f_{c,cyl,100/300}$	Cylinder ø100 X H300
$f_{c,cyl,70/150}$	$f_{c,cyl} = (1.0/1.06)\ f_{c,cyl,70/150}$	Cylinder ø70 X H150
$f_{c,cyl,120/360}$	$f_{c,cyl} = (1.0/0.95)\ f_{c,cyl,120/360}$	Cylinder ø120 X H360
$f_{c,cyl,100/200}$	$f_{c,cyl} = (0.92/0.95)\ f_{c,cyl,100/200}$	Cylinder ø100 X H200
$f_{c,cube200}$	$f_{c,cube} = 1.05\ f_{c,cube200}$	Cube 200 X 200
$f_{c,cube100}$	$f_{c,cube} = 0.90\ f_{c,cube100}$	Cube 100 X 100

A dozen AI and ML techniques:

- A.Tikhonov Regularization.
- A.Elastic Net.
- A.Stochastic Gradient Descent.
- A.Multilayer Perceptron.
- A.Ensemble Learning.
- A.Stacking Regressors.
- A.Voting Regressor.
- A.Histogram-based Gradient Boosting Regression Tree.

to find the best solution from multiple aspects like accuracy, and speed, and the number of outliers.

A. Tikhonov Regularization

The Tikhonov regularization method is a powerful alternative for regularization of nonlinear system identification problems

We got a validation result of 66% which is not good enough

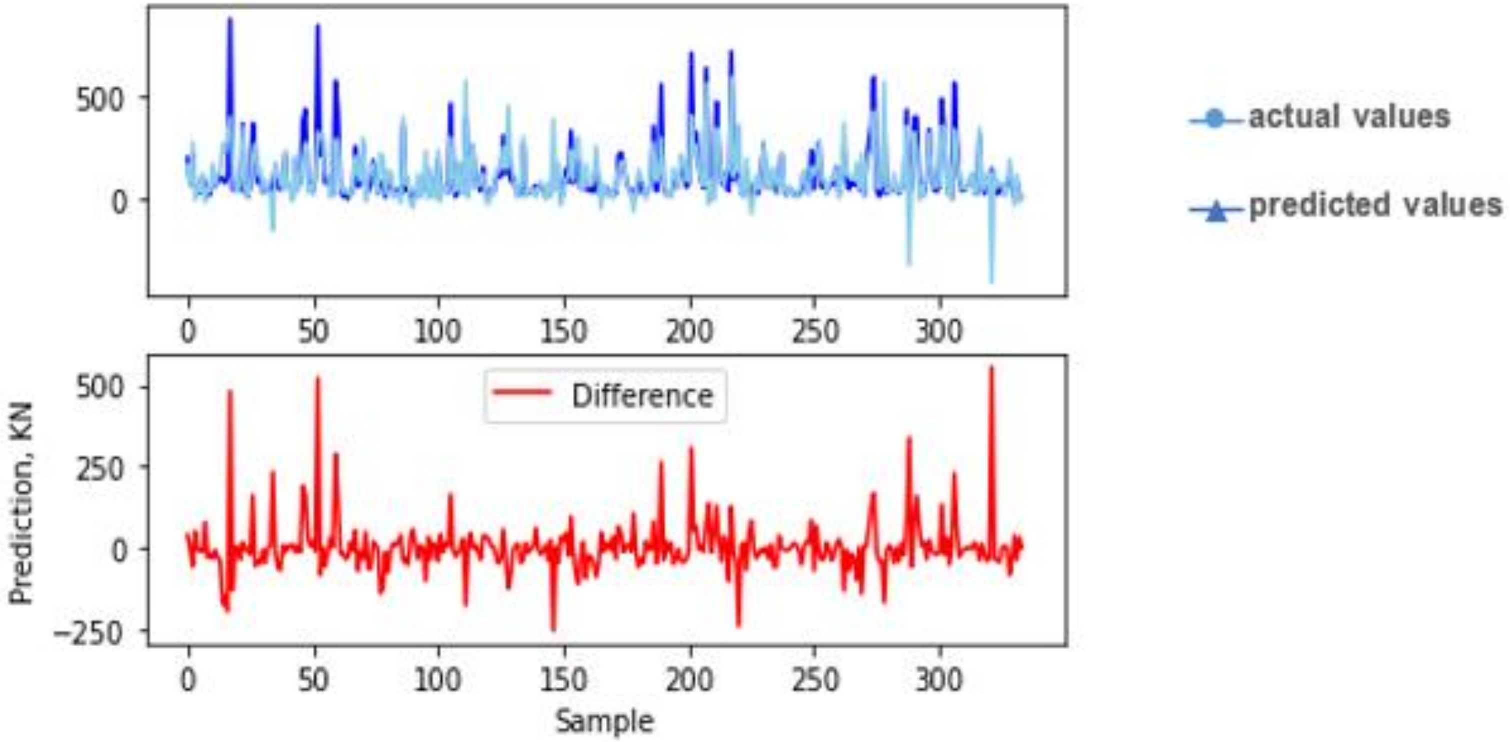
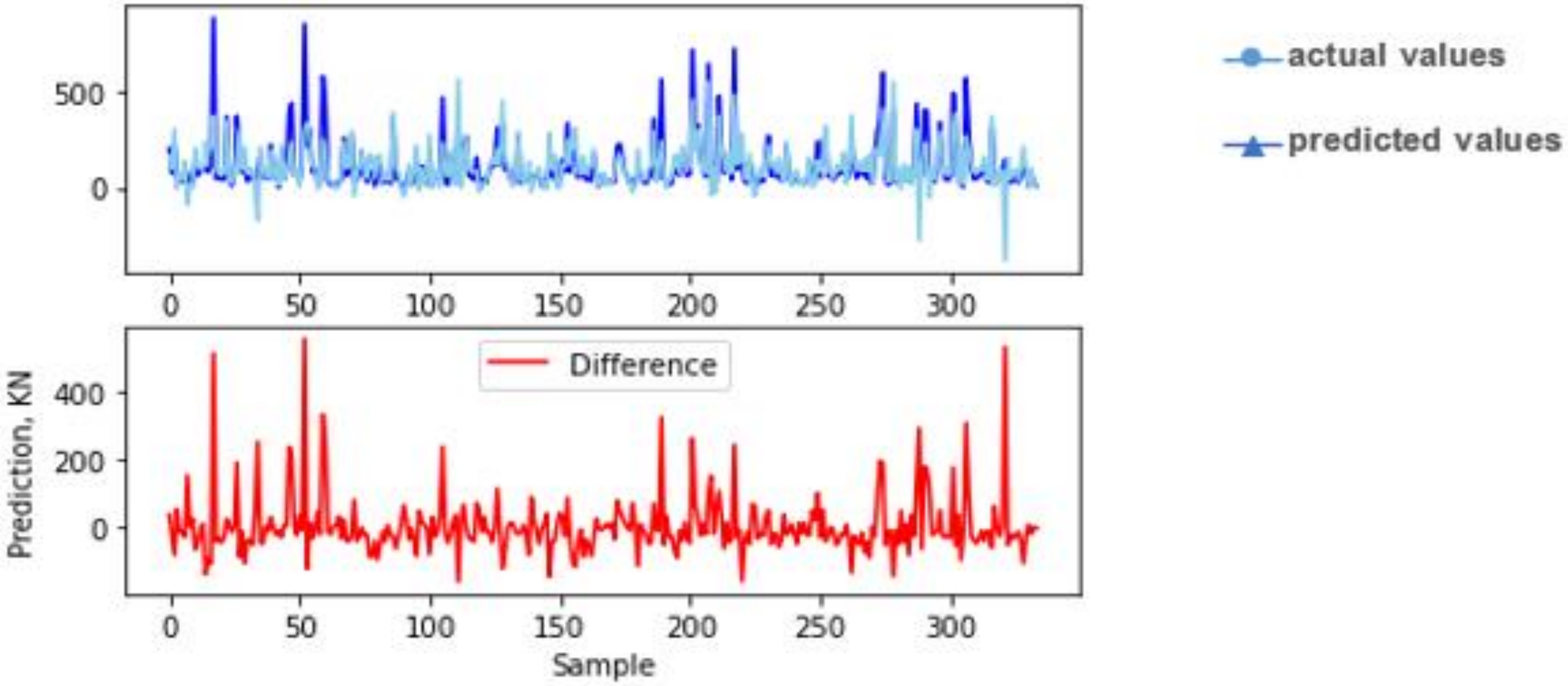


Fig 1. Ridge regression results.

Elastic Net combines:

- Tikhonov regularization
- With LASSO regression

Our model was able to get worse results at 63%.



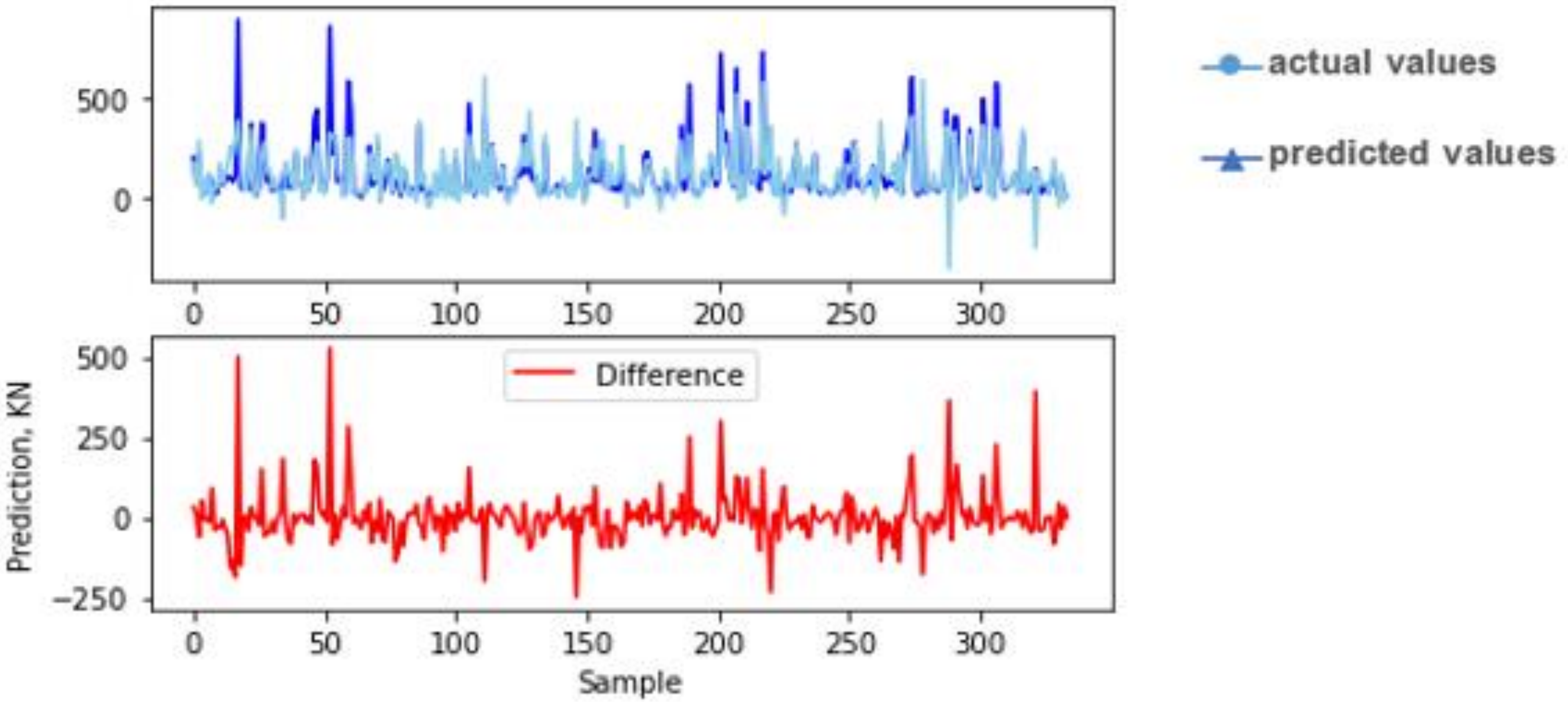
Fig, 2. The elastic net regression result.

C. Stochastic Gradient Descent

SGD is an iterative method for optimizing an object function

→ **it is a form of stochastic approximation of gradient descent optimization**

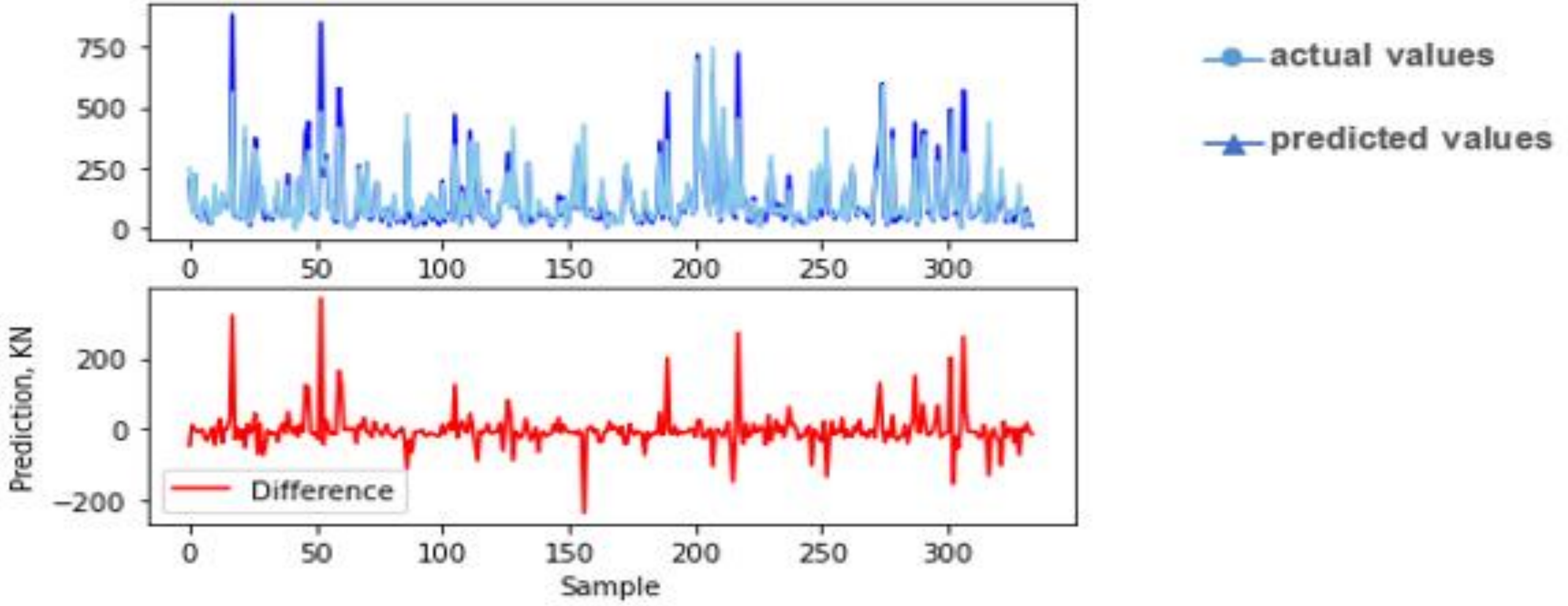
→ **In our tests, it got the result of 68%, slightly better than Tikhonov regularization.**



Fig, 3. SGD regression result

D. Multilayer Perceptron

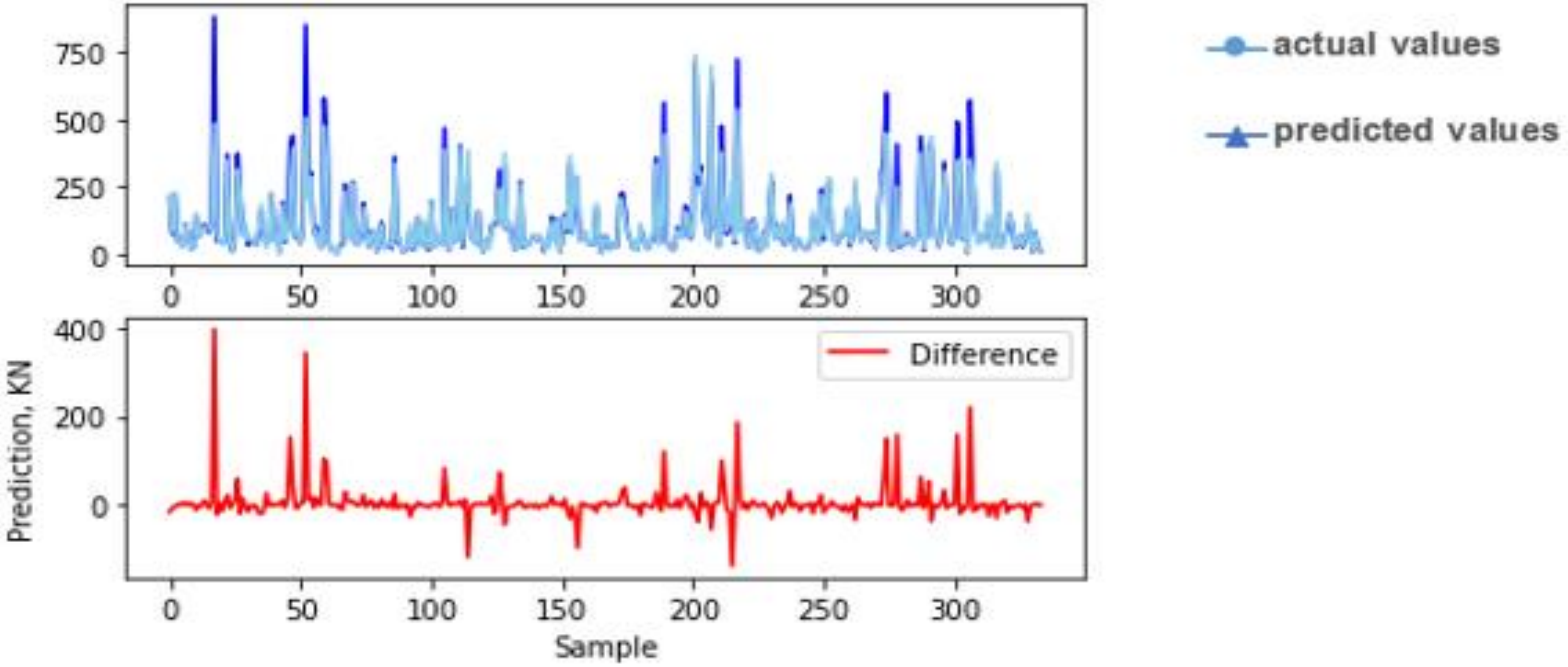
- **MLP for short proved to be very good in understanding the relationship between the input and output**
- **The MLP consists of three or more layers (an input and an output layer with one or more hidden layers).**
- **After building our regressor based on MLP we had a result of 89% .**



Fig, 4. MLP regression result

E. Ensemble Learning

- **An ensemble is itself a supervised learning algorithm because it can be trained and then used to make predictions.**
- **Empirically, ensembles tend to yield better results when there is significant diversity among the models.**
- **a result of this method 90% is obtained which is better than MLP by 1%.**

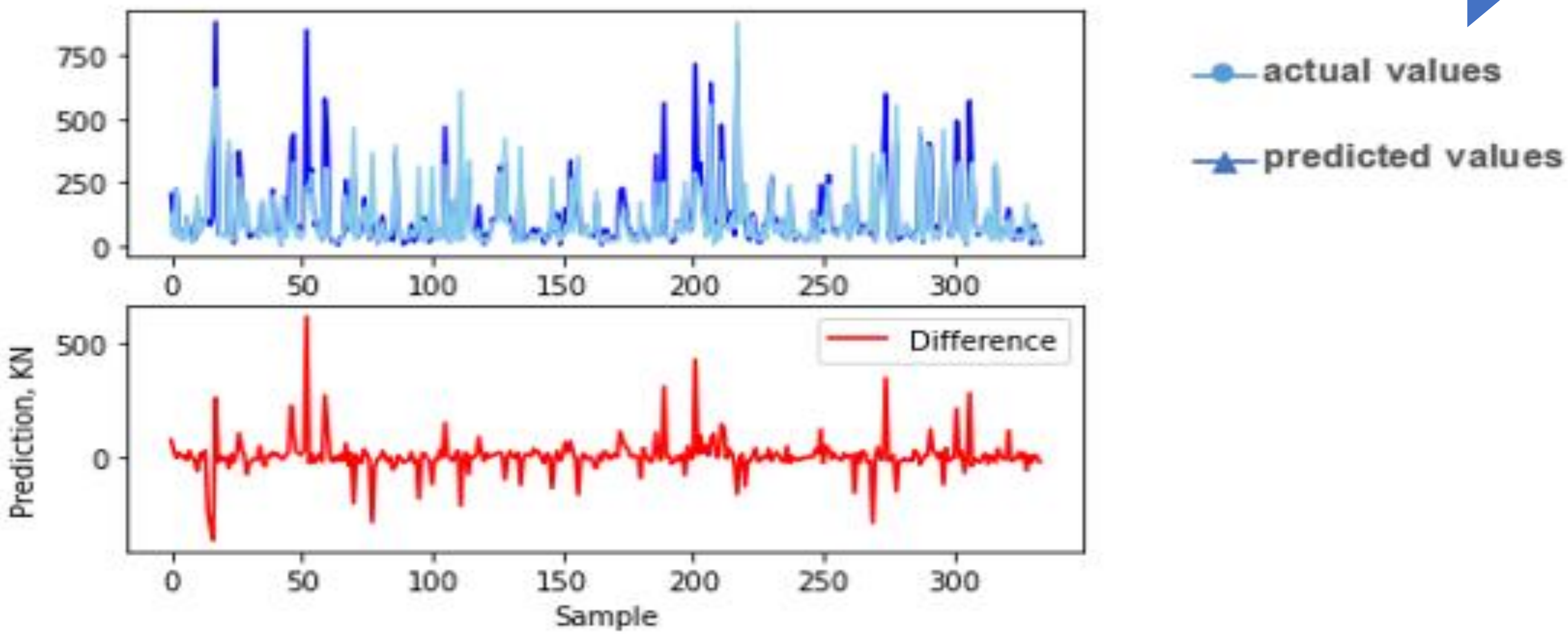


Fig, 5. Randomized decision trees results.

F. Stacking Regressors

Stacking allows to use of the strength of each estimator by using their output as the input of a final estimator [8].

after testing we found that the extra complication yielded a result of 69%.



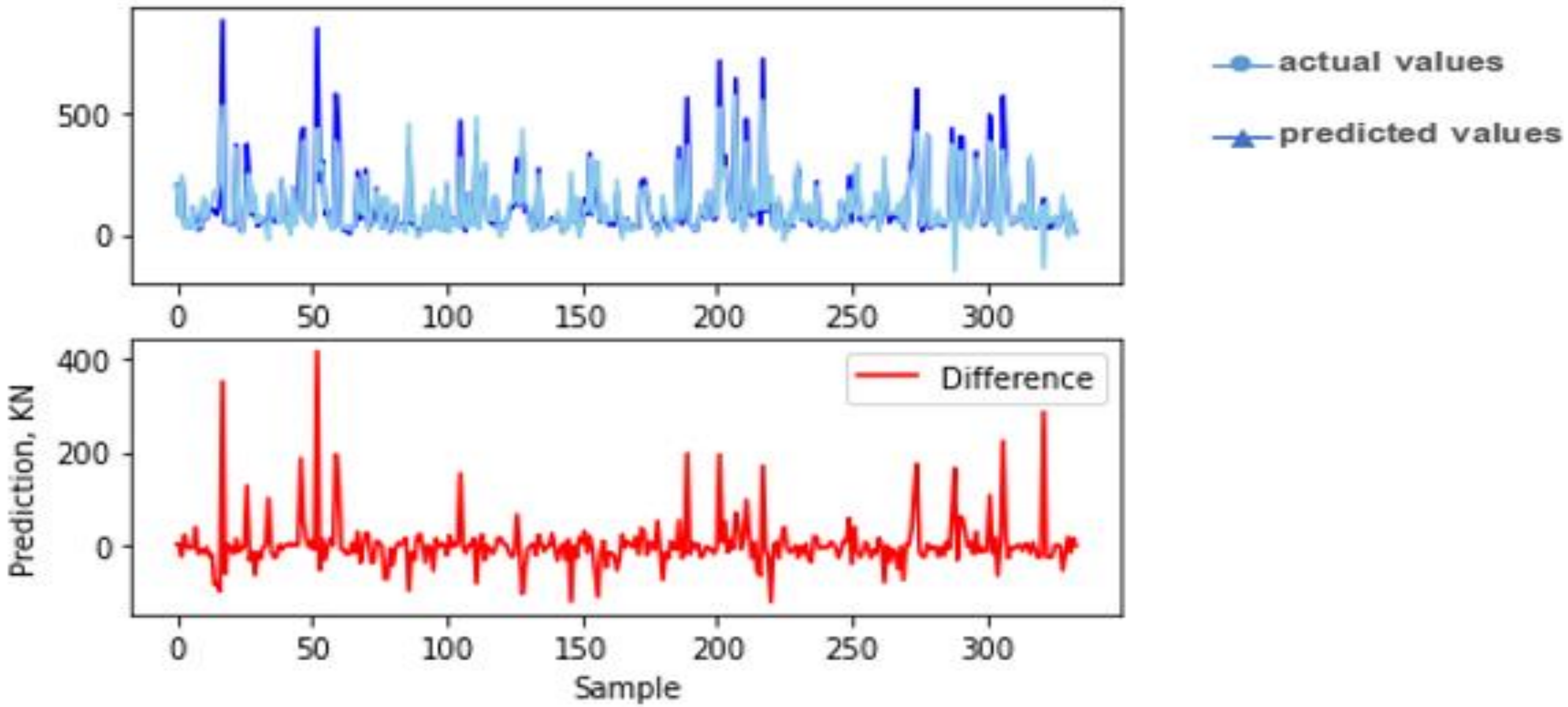
Fig, 6. Result of stacking multiple regressors.

G. Voting Regressor

Voting Regressor did not take time in training as the stacking regressor yet.

it averages the individual predictions to form a final prediction [9].

it gets a result of 85% but without any use of neural networks



Fig, 7. Result of a voting regressor.

H. Histogram-based Gradient Boosting Regression Tree

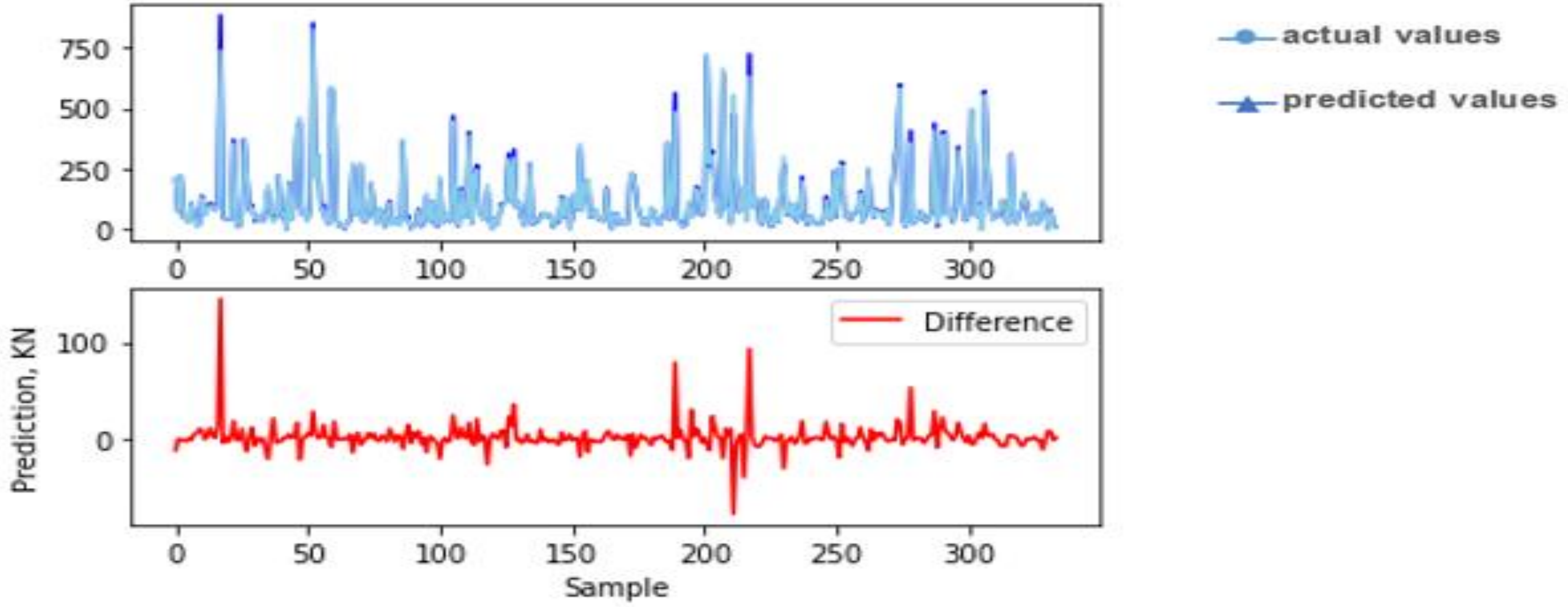
Gradient boosting is one of the most powerful techniques for building predictive models

Hypothesis boosting was the idea of filtering observations, focusing on developing new weak learns

Gradient boosting is typically used with decision trees (especially CART trees) of a fixed size as base learners

An unprecedented 96% was acquired using histogram-based gradient boosting regression trees.

also the outliers are smaller in quantity and value.

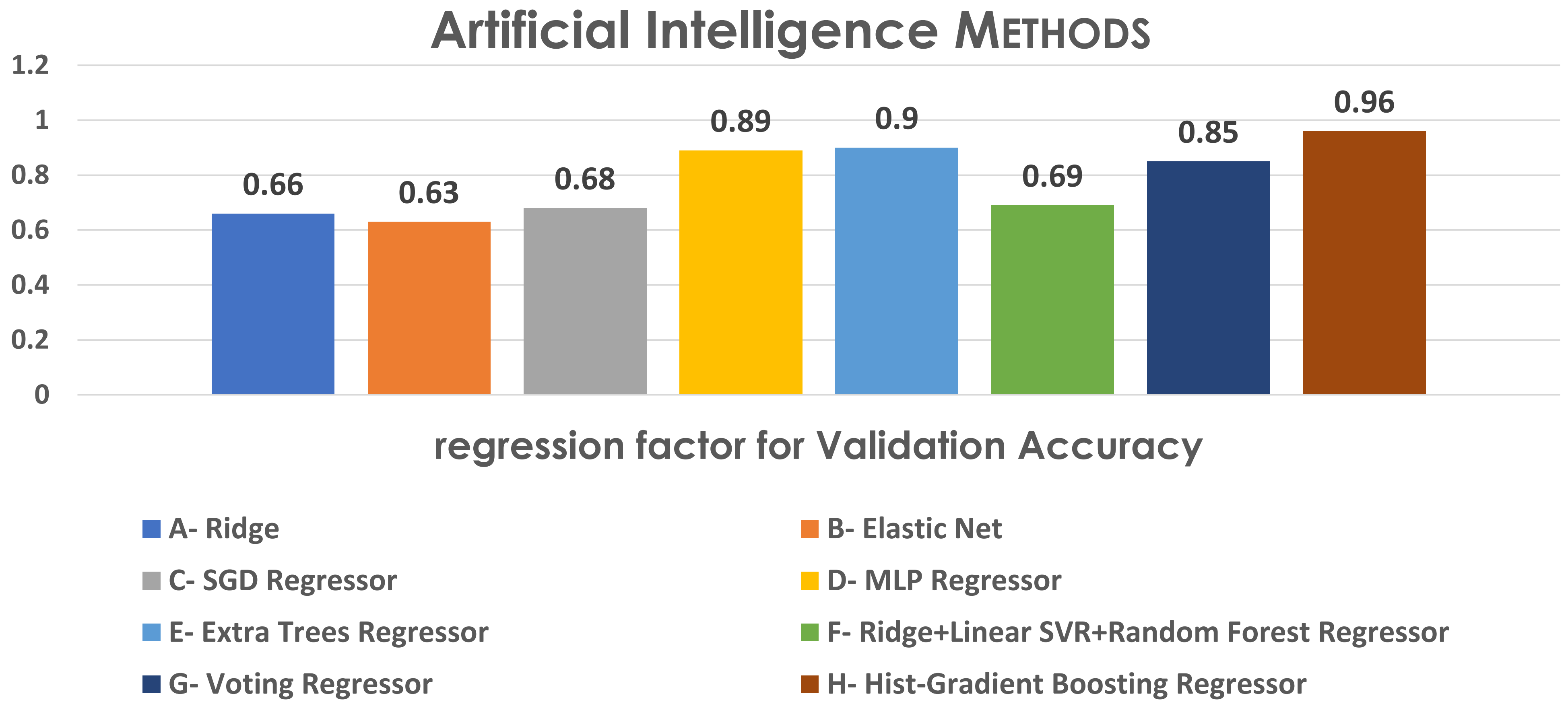


Fig, 8. Result of Histogram-Based Gradient Boosting Regression Tree.

- **Table (4)** shows training, test, and validation results for multiple machine learning and artificial intelligence methods.

Table .4: Multiple algorithms scores.

Algorithm	Training Accuracy	Test Accuracy	Validation Accuracy
A- Ridge	0.73	0.63	**0.66**
B- Elastic Net	0.68	0.58	**0.63**
C- SGD Regressor	0.73	0.64	**0.68**
D- MLP Regressor	0.90	0.85	**0.89**
E- Extra Trees Regressor	0.99	0.90	**0.90**
F- Ridge+Linear SVR+Random Forest Regressor	0.76	0.65	**0.69**
G- Voting Regressor	0.91	0.83	**0.85**
H- Hist-Gradient Boosting Regressor	0.97	0.98	**0.96**



Fig, 9. Result of regression factor for Validation Accuracy of AI Methods

- **The histogram-based gradient boosting regression** gave the **best results** with the smallest number of outliers, and the highest accuracy compared to other artificial intelligence and machine learning methods.

1. A total of 8 techniques has been evaluated for solving the problem of beam strength prediction, The techniques were applied on data collection shear databank (**ESDB database**).
2. Root mean squared error was used to evaluate the predicted values.
3. the comparison metric was the validation accuracy, which uses unseen data for evaluation.
4. Histogram Gradient boosting regressor a machine learning technique has outperformed the best in class predictor namely the MLP neural network.
5. It is an indicator that the nature of this problem could be solved with far simpler architectures than neural networks.
6. Developing new models and experimenting with different setups and configurations has been conducted to explore the usage of AI in the field of beam strength prediction.

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