Action 3.6

Technical guidelines for the field implementation of the “wet” technology with the use of reclaimed asphalt pavement (RAP)

POLITECNICO DI TORINO

Project partners

With the contribution of

These technical guidelines were prepared as a result of the activities carried out in Action 3.6, focused on the implementation of the "wet" production process with the use of reclaimed asphalt pavement (RAP) material in partial substitution of virgin aggregates. Reduced-scale pavement sections were built and corresponding materials were subjected to analysis.

The site selected for trials was the parking lot of a shopping mall (Gross Iper), located in the territory of the city of Leinì (Torino). As shown in the Report provided in attachment (identified as one of the deliverables of the TYREC4LIFE project), the total paving surface covered by paving trials was equal to 9,600 m^2, with a target laying thickness of 3 cm. Based on the requests of the owner of the infrastructure, it was agreed that the individual mixtures would be placed in different areas as indicated in the following:

- The gap-graded mixtures containing RAP on the access road to the parking lot, on a total surface of approximately 2,000 m^2 (subjected to a higher volume of moving traffic);
- The reference gap-graded mixture on a limited portion, of approximately 1,800 m^2, of the parking lot;
- The dense-graded mixture on the rest of the parking lot, on a total area of approximately 5,800 m^2.

Production and construction activities were carried out by the Beneficiary of the Action (Brillada Vittorio & C.) on September 20th, 2015. Monitoring activities and subsequent testing were performed by the Politecnico di Torino. No major problem was reported in any phase of the Action.

Bituminous mixtures were produced in the same plant, owned and operated by Sintexcal s.p.a., which provided those which were laid as part of Actions 4.1 and 4.2. The asphalt rubber binder was also similar to the one employed in these Actions since it was once again supplied by Asphalt Rubber Italia (the only Italian producer). Job mix formulae were defined on the basis of the information gathered in Action 3.2 and on supplementary information obtained from the production plant.

Laying of the bituminous mixtures occurred after the preliminary cleaning of the existing pavement surface, followed by the application of an emulsion tack coat. Laying was carried out by employing a standard paver, while compaction was thereafter performed by making use of a tandem vibrating roller (Dynapac CC232HF).

During laying operations samples of the bituminous mixtures were taken from the paver and thereafter employed in the laboratory for the assessment of their composition and for the evaluation of their volumetric and mechanical properties (following Marshall or gyratory compaction).


GAP GRADED + AR + RAP
GAP GRADED + AR
DENSE GRADED + AR
USCITA
ENTRATA


Carrefour
DYNAPAC


DYNAPAC


DYNAPAC


F121 GW


DYNAPAC
DYNAPAC

GAP GRADED

Binder content

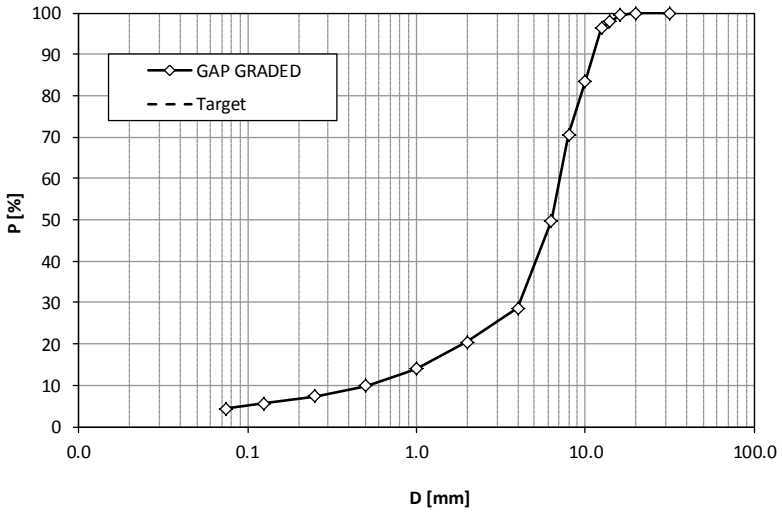
Tare	Net $W_{ante\ ignition}$	Gross $W_{ante\ ignition}$	Gross $W_{post\ ignition}$	Net $W_{post\ ignition}$	$\%B_{mixture}$
[g]	[g]	[g]	[g]	[g]	[%]
2830.4	1193.0	4023.4	3924.3	1093.9	**8.3**

$\%B_{aggregates}$ [%]	
Extraction	Target
9.1	4.1

Particle size distribution

Sieve	Retained	$Retained_{prog}$	$Retained_{prog}$	$Passing_{prog}$
[mm]	[g]	[g]	[%]	[%]
31.5	0.0	0.0	0.0	100.0
20	0.0	0.0	0.0	100.0
16	6.5	6.5	0.6	99.4
14	16.1	22.6	2.1	97.9
12.5	17.9	40.5	3.7	96.3
10	140.0	180.5	16.5	83.5
8	140.9	321.4	29.4	70.6
6.3	229.0	550.4	50.3	49.7
4	231.2	781.6	71.5	28.5
2	88.3	869.9	79.5	20.5
1	71.2	941.1	86.0	14.0
0.5	44.3	985.4	90.1	9.9
0.25	27.5	1012.9	92.6	7.4
0.125	19.0	1031.9	94.3	5.7
0.075	13.9	1045.8	95.6	4.4
Filler	48.1	1045.8	95.6	-
Somma	1093.9			

Sieve	Passing [%]	
[mm]	Extraction	Target
31.5	100	
20	100	
16	99	
14	98	
12.5	96	
10	83	
8	71	
6.3	50	
4	29	
2	20	
1	14	
0.5	10	
0.25	7	
0.125	6	
0.075	4.4	



DENSE GRADED

Binder content

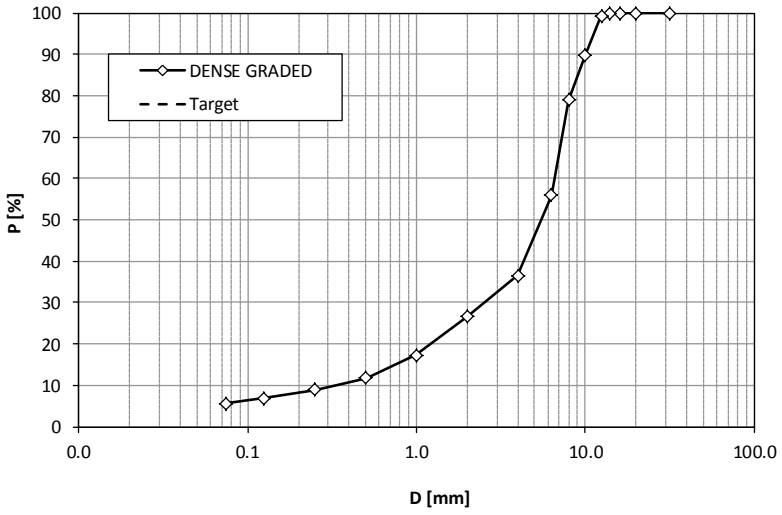
Tare	Net $W_{ante\ ignition}$	Gross $W_{ante\ ignition}$	Gross $W_{post\ ignition}$	Net $W_{post\ ignition}$	$\%B_{mixture}$
[g]	[g]	[g]	[g]	[g]	[%]
2838.4	1173.8	4012.2	3944.8	1106.4	**5.7**

$\%B_{aggregates}$ [%]	
Extraction	Target
6.1	4.2

Particle size distribution

Sieve	Retained	$Retained_{prog}$	$Retained_{prog}$	$Passing_{prog}$
[mm]	[g]	[g]	[%]	[%]
31.5	0.0	0.0	0.0	100.0
20	0.0	0.0	0.0	100.0
16	0.0	0.0	0.0	100.0
14	0.0	0.0	0.0	100.0
12.5	7.0	7.0	0.6	99.4
10	105.5	112.5	10.2	89.8
8	121.0	233.5	21.1	78.9
6.3	254.4	487.9	44.1	55.9
4	214.9	702.8	63.5	36.5
2	110.0	812.8	73.5	26.5
1	102.6	915.4	82.7	17.3
0.5	60.7	976.1	88.2	11.8
0.25	32.2	1008.3	91.1	8.9
0.125	21.8	1030.1	93.1	6.9
0.075	14.9	1045.0	94.5	5.5
Filler	61.4	1106.4	100.0	-
Somma	1106.4			

Sieve	Passing [%]	
[mm]	Extraction	Target
31.5	100	
20	100	
16	100	
14	100	
12.5	99	
10	90	
8	79	
6.3	56	
4	36	
2	27	
1	17	
0.5	12	
0.25	9	
0.125	7	
0.075	5.5	



GAP NO RAP

Binder content

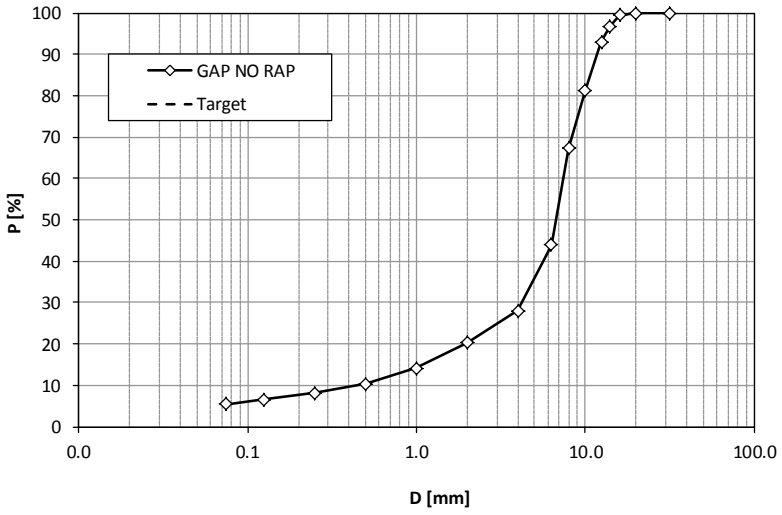
Tare	Net $W_{ante\ ignition}$	Gross $W_{ante\ ignition}$	Gross $W_{post\ ignition}$	Net $W_{post\ ignition}$	$\%B_{mixture}$
[g]	[g]	[g]	[g]	[g]	[%]
2838.4	1214.0	4052.4	3950.2	1111.8	**8.4**

$\%B_{aggregates}$ [%]	
Extraction	Target
9.2	4.3

Particle size distribution

Sieve	Retained	$Retained_{prog}$	$Retained_{prog}$	$Passing_{prog}$
[mm]	[g]	[g]	[%]	[%]
31.5	0.0	0.0	0.0	100.0
20	0.0	0.0	0.0	100.0
16	7.0	7.0	0.6	99.4
14	29.5	36.5	3.3	96.7
12.5	41.9	78.4	7.1	92.9
10	129.5	207.9	18.7	81.3
8	155.8	363.7	32.7	67.3
6.3	258.9	622.6	56.0	44.0
4	178.3	800.9	72.0	28.0
2	85.8	886.7	79.8	20.2
1	69.0	955.7	86.0	14.0
0.5	41.0	996.7	89.6	10.4
0.25	24.7	1021.4	91.9	8.1
0.125	18.1	1039.5	93.5	6.5
0.075	12.5	1052.0	94.6	5.4
Filler	59.8	1111.8	100.0	-
Somma	1111.8			

Sieve	Passing [%]	
[mm]	Extraction	Target
31.5	100	
20	100	
16	99	
14	97	
12.5	93	
10	81	
8	67	
6.3	44	
4	28	
2	20	
1	14	
0.5	10	
0.25	8	
0.125	7	
0.075	5.4	



GAP GRADED

	M_P	M_{P+M}	$M_{P+M+H2O}$	V_P	T	ρ_w	ρ_{mw}
	[g]	[g]	[g]	[m^3]	[°C]	[kg/m^3]	[kg/m^3]
9F	921.8	1488.8	2586.1	0.001328	19.4	998.4	2482
PI	855.8	1471.7	2616.0	0.001394	19.4	998.4	2481
						Media	**2481**
						Dev.St.	**1**
						C.V.	**0.0**

DENSE GRADED

	M_P	M_{P+M}	$M_{P+M+H2O}$	V_P	T	ρ_w	ρ_{mw}
	[g]	[g]	[g]	[m^3]	[°C]	[kg/m^3]	[kg/m^3]
9F	921.8	1527.5	2616.8	0.001328	20.8	998.1	2565
PI	855.8	1451.9	2611.1	0.001394	20.8	998.1	2558

Media	**2562**
Dev.St.	**5**
C.V.	**0.2**

GAP NO RAP

	M_P	M_{P+M}	$M_{P+M+H2O}$	V_P	T	ρ_w	ρ_{mw}
	[g]	[g]	[g]	[m^3]	[°C]	[kg/m^3]	[kg/m^3]
9F	921.8	1423.7	2546.0	0.001328	19.4	998.4	2468
PI	855.8	1518.4	2642.8	0.001394	19.4	998.4	2471

Media	**2469**
Dev.St.	**2**
C.V.	**0.1**

DENSE GRADED

ID	h_1	h_2	h_3	h_4	h_{media}
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
DENSE GRADED 1	64.6	64.6	64.6	64.6	64.6
DENSE GRADED 2	64.3	64.3	64.3	64.3	64.3
DENSE GRADED 3	65.5	65.5	65.5	65.5	65.5
DENSE GRADED 4	63.8	63.8	63.8	63.8	63.8

ID	m_{aria}	h_{media}	ρ_{geo}	ρ_{mw}	v_{geo}
[-]	[g]	[mm]	[kg/m^3]	[kg/m^3]	[%]
DENSE GRADED 1	1216.0	64.6	2322	2481	6.4
DENSE GRADED 2	1199.8	64.3	2302	2481	7.2
DENSE GRADED 3	1211.5	65.5	2281	2481	8.1
DENSE GRADED 4	1200.6	63.8	2321	2481	6.5

Media	7.1
Dev.St.	0.8
C.V.	11.0

ID	m_{aria}	m_{acqua}	m_{SSD}	T	ρ_w	ρ_{SSD}	ρ_{mw}	v
[-]	[g]	[g]	[g]	[°C]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[%]
DENSE GRADED 1	1216.0	713.5	1221.4	19.0	998.5	2391	2562	6.7
DENSE GRADED 2	1199.8	703.0	1207.5	19.0	998.5	2375	2562	7.3
DENSE GRADED 3	1211.5	711.3	1217.6	19.0	998.5	2389	2562	6.7
DENSE GRADED 4	1200.6	704.5	1206.8	19.0	998.5	2387	2562	6.8
							Media	6.9
							Dev.St.	0.3
							C.V. [%]	4.1

GAP GRADED

ID	h_1	h_2	h_3	h_4	h_{media}
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
GAP GRADED 1	64.5	64.5	64.5	64.5	64.5
GAP GRADED 2	64.5	64.5	64.5	64.5	64.5
GAP GRADED 3	63.5	63.5	63.5	63.5	63.5
GAP GRADED 4	64.0	64.0	64.0	64.0	64.0

ID	m_{aria}	h_{media}	ρ_{geo}	ρ_{mw}	v_{geo}
[-]	[g]	[mm]	[kg/m^3]	[kg/m^3]	[%]
GAP GRADED 1	1207.1	64.5	2308	2562	9.9
GAP GRADED 2	1203.9	64.5	2302	2562	10.1
GAP GRADED 3	1191.6	63.5	2315	2562	9.6
GAP GRADED 4	1197.4	64.0	2308	2562	9.9

Media	9.9
Dev.St.	0.2
C.V.	2.0

ID	m_{aria}	m_{acqua}	m_{SSD}	T	ρ_w	ρ_{SSD}	ρ_{mw}	v
[-]	[g]	[g]	[g]	[°C]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[%]
GAP GRADED 1	1207.1	705.0	1209.3	19.0	998.5	2390	2481	3.7
GAP GRADED 2	1203.9	704.0	1207.6	19.0	998.5	2387	2481	3.8
GAP GRADED 3	1191.6	700.0	1193.7	19.0	998.5	2410	2481	2.9
GAP GRADED 4	1197.4	701.0	1201.1	19.0	998.5	2391	2481	3.7

Media	3.5
Dev.St.	0.4
C.V. [%]	12.1

GAP NO RAP

ID	h_1	h_2	h_3	h_4	h_{media}
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
GAP NO RAPE 1	64.2	64.2	64.2	64.2	64.2
GAP NO RAPE 2	63.5	63.5	63.5	63.5	63.5
GAP NO RAPE 3	63.5	63.5	63.5	63.5	63.5
GAP NO RAPE 4	63.6	63.6	63.6	63.6	63.6

ID	m_{aria}	h_{media}	ρ_{geo}	ρ_{mw}	v_{geo}
[-]	[g]	[mm]	[kg/m^3]	[kg/m^3]	[%]
GAP NO RAPE 1	1213.0	64.2	2330	2469	5.6
GAP NO RAPE 2	1209.7	63.5	2350	2469	4.8
GAP NO RAPE 3	1208.6	63.5	2348	2469	4.9
GAP NO RAPE 4	1208.7	63.6	2344	2469	5.1

Media	5.1
Dev.St.	0.4
C.V.	6.9

ID	m_{aria}	m_{acqua}	m_{SSD}	T	ρ_w	ρ_{SSD}	ρ_{mw}	v
[-]	[g]	[g]	[g]	[°C]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[%]
GAP NO RAPE 1	1213.0	713.0	1214.8	19.0	998.5	2414	2469	2.2
GAP NO RAPE 2	1209.7	711.0	1211.0	19.0	998.5	2416	2469	2.2
GAP NO RAPE 3	1208.6	711.0	1210.6	19.0	998.5	2415	2469	2.2
GAP NO RAPE 4	1208.7	710.0	1210.7	19.0	998.5	2410	2469	2.4

Media	2.2
Dev.St.	0.1
C.V. [%]	4.5

DENSE GRADED

ID	h_1	h_2	h_3	h_4	h_{media}
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
DENSE GRADED 1	65.00	65.00	65.00	65.00	65.0
DENSE GRADED 2	65.00	65.00	65.00	65.00	65.0
DENSE GRADED 3	64.00	64.00	64.00	64.00	64.0
DENSE GRADED 4	63.60	63.50	63.60	63.60	63.6

ID	m_{aria}	h_{media}	ρ_{geo}	ρ_{mw}	v_{geo}
[-]	[g]	[mm]	[kg/m^3]	[kg/m^3]	[%]
DENSE GRADED 1	1205.1	65.0	2287	2562	10.7
DENSE GRADED 2	1189.5	65.0	2257	2562	11.9
DENSE GRADED 3	1195.6	64.0	2304	2562	10.0
DENSE GRADED 4	1185.1	63.6	2298	2562	10.3

Media	10.9
Dev.St.	0.9
C.V.	8.5

ID	m_{aria}	m_{acqua}	m_{SSD}	T	ρ_w	ρ_{SSD}	ρ_{mw}	v
[-]	[g]	[g]	[g]	[°C]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[%]
DENSE GRADED 1	1205.1	700.8	1214.3	18.0	998.7	2344	2562	8.5
DENSE GRADED 2	1189.5	692.9	1199.7	18.0	998.7	2344	2562	8.5
DENSE GRADED 3	1195.6	698.9	1205.0	18.0	998.7	2359	2562	7.9
DENSE GRADED 4	1185.1	695.0	1190.2	18.0	998.7	2390	2562	6.7
							Media	8.3
							Dev.St.	0.3
							C.V. [%]	4.2

GAP GRADED

ID	h_1	h_2	h_3	h_4	h_{media}
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
GAP GRADED 1	63.0	63.0	63.0	63.0	63.0
GAP GRADED 2	63.5	63.5	63.5	63.5	63.5
GAP GRADED 3	63.5	63.5	63.5	63.5	63.5
GAP GRADED 4	63.5	63.5	63.5	63.5	63.5

ID	m_{aria}	h_{media}	ρ_{geo}	ρ_{mw}	v_{geo}
[-]	[g]	[mm]	[kg/m^3]	[kg/m^3]	[%]
GAP GRADED 1	1187.7	63.0	2325	2481	6.3
GAP GRADED 2	1194.2	63.5	2320	2481	6.5
GAP GRADED 3	1191.3	63.5	2314	2481	6.7
GAP GRADED 4	1189.9	63.5	2311	2481	6.9

Media	6.5
Dev.St.	0.2
C.V.	3.5

ID	m_{aria}	m_{acqua}	m_{SSD}	T	ρ_w	ρ_{SSD}	ρ_{mw}	v
[-]	[g]	[g]	[g]	[°C]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[%]
GAP GRADED 1	1187.7	696.2	1190.6	18.0	998.7	2399	2481	3.3
GAP GRADED 2	1194.2	697.2	1196.7	18.0	998.7	2388	2481	3.8
GAP GRADED 3	1191.3	697.5	1193.8	18.0	998.7	2397	2481	3.4
GAP GRADED 4	1189.9	695.0	1192.7	18.0	998.7	2388	2481	3.8

Media	3.5
Dev.St.	0.2
C.V. [%]	7.1

GAP NO RAP

ID	h_1	h_2	h_3	h_4	h_{media}
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
GAP NO RAPE 1	64.0	64.0	64.0	64.0	64.0
GAP NO RAPE 2	64.0	64.0	64.0	64.0	64.0
GAP NO RAPE 3	63.5	63.5	63.5	63.5	63.8
GAP NO RAPE 4	63.5	63.5	63.5	63.5	63.5

ID	m_{aria}	h_{media}	ρ_{geo}	ρ_{mw}	v_{geo}
[-]	[g]	[mm]	[kg/m^3]	[kg/m^3]	[%]
GAP NO RAPE 1	1196.0	64.0	2305	2469	6.6
GAP NO RAPE 2	1195.8	64.0	2305	2469	6.7
GAP NO RAPE 3	1192.7	63.8	2306	2469	6.6
GAP NO RAPE 4	1193.2	63.5	2318	2469	6.1

Media	6.6
Dev.St.	0.0
C.V.	0.4

ID	m_{aria}	m_{acqua}	m_{SSD}	T	ρ_w	ρ_{SSD}	ρ_{mw}	v
[-]	[g]	[g]	[g]	[°C]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[%]
GAP NO RAPE 1	1196.0	698.6	1199.9	18.0	998.7	2383	2469	3.5
GAP NO RAPE 2	1195.8	699.0	1198.9	18.0	998.7	2389	2469	3.2
GAP NO RAPE 3	1192.7	698.5	1195.1	18.0	998.7	2399	2469	2.9
GAP NO RAPE 4	1193.2	700.0	1197.4	18.0	998.7	2396	2469	3.0

Media	3.2
Dev.St.	0.3
C.V. [%]	10.1

		DENSE GRADED 1A	DENSE GRADED 1B	DENSE GRADED 1C	DENSE GRADED 1D	DENSE GRADED 2A	DENSE GRADED 2B	DENSE GRADED 2C	DENSE GRADED 2D
F_{max}	[N]	2812.00	2769.00	2290.00	2661.00	3353.00	3002.00	3057.00	3001.00
ΔW	[mm]	1.70	1.61	1.25	1.31	1.25	1.66	1.40	1.30
ε_{max}	[%]	2.33	2.21	1.72	1.79	1.71	2.28	1.92	1.78
σ_{max}	[N/mm2]	1.50	1.48	1.22	1.42	1.77	1.59	1.62	1.59
$K_{1,c}$	N/mm3/2	8.93	8.80	7.28	8.45	10.55	9.45	9.62	9.45
U_{fmax}	[Nmm]	2769.91	2780.59	1566.23	2157.84	2791.47	2663.42	2369.37	2474.53
		GAP GRADED 1A	GAP GRADED 1B	GAP GRADED 1C	GAP GRADED 1D	GAP GRADED 2A	GAP GRADED 2B	GAP GRADED 2C	GAP GRADED 2D
F_{max}	[N]	2713.00	3057.00	3003.00	2691.00	2695.00	2887.00	3263.00	3484.00
ΔW	[mm]	1.84	1.40	0.95	1.62	1.12	1.78	1.89	1.69
ε_{max}	[%]	2.50	1.91	1.30	2.21	1.53	2.43	2.58	2.32
σ_{max}	[N/mm2]	1.64	1.85	1.82	1.63	1.62	1.73	1.96	2.09
$K_{1,c}$	N/mm3/2	9.79	11.03	10.84	9.71	9.63	10.32	11.66	12.45
U_{fmax}	[Nmm]	3279.17	2369.37	2032.74	2438.66	2270.43	2999.94	3409.82	3522.97
		GAP NO RAP 1A	GAP NO RAP 1B	GAP NO RAP 1C	GAP NO RAP 1D	GAP NO RAP 2A	GAP NO RAP 2B	GAP NO RAP 2C	GAP NO RAP 2D
F_{max}	[N]	2833.00	2994.00	2920.00	2823.00	3323.00	3513.00	3026.00	3183.00
ΔW	[mm]	1.67	1.72	1.84	1.47	2.46	2.52	1.70	2.00
ε_{max}	[%]	2.29	2.35	2.52	2.02	3.37	3.45	2.32	2.74
σ_{max}	[N/mm2]	1.61	1.70	1.66	1.61	1.89	2.00	1.72	1.81
$K_{1,c}$	N/mm3/2	9.61	10.15	9.90	9.57	11.27	11.92	10.27	10.80
U_{fmax}	[Nmm]	2816.92	2984.02	3032.44	2624.30	4157.26	4440.77	3352.15	3425.71

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