Sample

April 28, 2021

[1]:
```
import pandas as pd
from copy import deepcopy
import matplotlib.pyplot as plt
import re
import numpy as np
from matplotlib import gridspec
import matplotlib
```

1 Helper functions

These are borrowed from the `Convert.ipynb` file.

[2]:
```
headings = ['Building Identifier',
            'Country',
             'City',
             'Quality / Stage of Data',
             'Construction Date',
             'Building Type',
             'Gross Floor Area']
```

[3]:
```
df = pd.read_excel('../Dataset/dataset.xlsx',header=1).drop('Unnamed: 0',axis=1)
```

[4]:
```
df
```

[4]:

	Building Identifier	Country	City	Quality / Stage of Data	\
0	1	CA	TOR	00IFC	
1	2	CA	TOR	00IFC	
2	3	CA	TOR	00IFC	
3	4	CA	TOR	00IFC	
4	5	CA	TOR	00IFC	
5	6	CA	TOR	00IFC	
6	7	CA	TOR	00IFC	
7	8	CA	TOR	00IFC	
8	9	CA	TOR	00IFC	
9	10	CA	TOR	00IFC	
10	11	CA	TOR	00IFC	
11	12	CA	TOR	00IFC	

12	13	CA	TOR	00IFC
13	14	CA	TOR	00IFC
14	15	CA	TOR	00IFC
15	16	CA	TOR	00IFC
16	17	CA	TOR	00IFC
17	18	CA	TOR	00IFC
18	19	CA	TOR	00IFC
19	20	CA	TOR	00IFC
20	21	CA	TOR	00IFC
21	22	CA	TOR	00IFC
22	23	CA	TOR	00IFC
23	24	CA	TOR	00IFC
24	25	CA	TOR	00IFC
25	26	CA	TOR	00IFC
26	27	CA	WIN	00IFC
27	28	CA	TOR	00IFC
28	29	CA	TOR	00IFC
29	30	CA	TOR	00IFC
30	31	CA	TOR	00IFC
31	32	CA	TOR	00IFC
32	33	CA	TOR	00IFC
33	34	CA	TOR	00IFC
34	35	CA	TOR	00IFC
35	36	CA	TOR	00IFC
36	37	CA	TOR	00IFC
37	38	CA	TOR	00IFC
38	39	CA	TOR	00IFC
39	40	US	NEW	00IFC
40	41	CA	TOR	00IFC
41	42	CA	TOR	00IFC
42	43	CA	TOR	00IFC
43	44	CA	TOR	00IFC
44	45	CA	TOR	00IFC
45	46	CA	TOR	00IFC
46	47	CA	TOR	00IFC
47	48	CA	RIC	0IARC
48	49	CA	TOR	00IFC
49	50	CA	TOR	00IFC
50	51	CA	TOR	00IFC
51	52	CA	TOR	00IFC
52	53	CA	TOR	00IFC
53	54	CA	TOR	00IFC
54	55	CA	TOR	00IFC
55	56	CA	TOR	00IFC
56	57	CA	TOR	00IFC
57	58	CA	TOR	00IFC
58	59	CA	TOR	0IFBP

59 60 CA TOR 0IFBP

	Construction Date	Building Type	Gross Floor Area	\
0	2021	SND	521.18	
1	2021	SND	389.24	
2	2021	SND	411.64	
3	2021	SND	269.56	
4	2011	OFF	11248.00	
5	2011	APB	11317.00	
6	2021	SND	445.99	
7	2021	SND	438.45	
8	2021	SND	714.07	
9	2021	SND	343.24	
10	2009	OFF	73083.00	
11	1917	SMR	199.93	
12	2021	SND	226.89	
13	2021	SND	611.73	
14	2021	SND	343.44	
15	2021	SND	613.38	
16	1969	SNR	413.72	
17	1969	SNR	333.49	
18	2021	SND	178.38	
19	2021	SND	323.80	
20	2020	SND	837.56	
21	2021	SND	587.86	
22	2021	SND	568.21	
23	2021	SMD	234.73	
24	2021	SND	294.84	
25	2021	SND	496.77	
26	2007	OFF	73600.00	
27	2021	SND	643.30	
28	2021	SND	701.61	
29	2021	SMD	257.75	
30	2021	SND	378.70	
31	2021	SND	324.16	
32	2020	SND	533.53	
33	2020	SMD	254.05	
34	2021	SND	423.03	
35	2021	SND	328.16	
36	2021	SND	421.59	
37	2020	SND	628.59	
38	2021	SND	464.51	
39	2017	EDU	8983.00	
40	2021	SND	346.14	
41	1913	SNR	161.08	
42	2021	SND	891.97	
43	2021	SND	525.61	

44	2021	SND	502.87
45	2021	SND	379.18
46	2021	SND	549.65
47	2016	EDU	6819.00
48	2020	SND	393.82
49	2021	SND	648.14
50	1988	INS	21934.00
51	2018	APB	53146.02
52	2018	MIX	33975.25
53	2017	APB	69784.00
54	2017	APB	39409.04
55	2016	APB	53871.00
56	2020	LNW	137.23
57	2020	LNW	144.92
58	2019	LNW	83.10
59	2021	LNW	234.79

	000_G2010.20.000_03 00 00.00_kg_1	000_B1010.20.000_03 00 00.00_kg_1	\
0	NaN	NaN	
1	NaN	NaN	
2	NaN	NaN	
3	NaN	NaN	
4	13704.0	1.776816e+06	
5	NaN	1.514400e+06	
6	NaN	NaN	
7	NaN	NaN	
8	NaN	NaN	
9	NaN	NaN	
10	58008.0	4.029264e+06	
11	NaN	NaN	
12	NaN	NaN	
13	NaN	NaN	
14	NaN	NaN	
15	NaN	NaN	
16	NaN	NaN	
17	NaN	NaN	
18	NaN	NaN	
19	NaN	NaN	
20	NaN	NaN	
21	NaN	NaN	
22	NaN	NaN	
23	NaN	NaN	
24	NaN	NaN	
25	NaN	NaN	
26	NaN	4.480680e+06	
27	NaN	NaN	
28	NaN	NaN	

29	NaN	NaN	
30	NaN	NaN	
31	NaN	NaN	
32	NaN	NaN	
33	NaN	NaN	
34	NaN	NaN	
35	NaN	NaN	
36	NaN	NaN	
37	NaN	NaN	
38	NaN	NaN	
39	NaN	2.191431e+04	
40	NaN	NaN	
41	NaN	NaN	
42	NaN	NaN	
43	NaN	NaN	
44	NaN	NaN	
45	NaN	NaN	
46	NaN	NaN	
47	NaN	3.756000e+04	
48	NaN	NaN	
49	NaN	NaN	
50	NaN	NaN	
51	NaN	NaN	
52	NaN	NaN	
53	NaN	NaN	
54	NaN	NaN	
55	NaN	NaN	
56	NaN	NaN	
57	NaN	NaN	
58	NaN	NaN	
59	NaN	NaN	

	000_C1010.10.000_04 22 00.00_kg_1	…	000_B2010.10.000_07 46 16.00_kg_2	\
0	NaN	…	NaN	
1	NaN	…	NaN	
2	NaN	…	NaN	
3	NaN	…	NaN	
4	19397.560000	…	NaN	
5	53877.650000	…	NaN	
6	NaN	…	NaN	
7	NaN	…	NaN	
8	NaN	…	NaN	
9	NaN	…	NaN	
10	562574.500000	…	NaN	
11	NaN	…	NaN	
12	NaN	…	NaN	
13	NaN	…	NaN	

14	NaN	…	NaN
15	NaN	…	NaN
16	NaN	…	NaN
17	NaN	…	NaN
18	NaN	…	NaN
19	NaN	…	NaN
20	NaN	…	NaN
21	NaN	…	NaN
22	NaN	…	NaN
23	NaN	…	NaN
24	NaN	…	NaN
25	NaN	…	NaN
26	354208.227500	…	NaN
27	NaN	…	NaN
28	NaN	…	NaN
29	NaN	…	NaN
30	NaN	…	NaN
31	NaN	…	NaN
32	NaN	…	NaN
33	NaN	…	NaN
34	NaN	…	NaN
35	NaN	…	NaN
36	NaN	…	NaN
37	NaN	…	NaN
38	NaN	…	NaN
39	8666.292723	…	NaN
40	NaN	…	NaN
41	NaN	…	NaN
42	NaN	…	NaN
43	NaN	…	NaN
44	NaN	…	NaN
45	NaN	…	NaN
46	NaN	…	NaN
47	NaN	…	NaN
48	NaN	…	NaN
49	NaN	…	NaN
50	NaN	…	NaN
51	8194.250000	…	NaN
52	191988.905000	…	NaN
53	82694.400000	…	NaN
54	46298.790000	…	NaN
55	422839.793489	…	NaN
56	NaN	…	NaN
57	NaN	…	NaN
58	NaN	…	NaN
59	NaN	…	67.3

	001_B2010.80.000_07 27 00.00_kg_2	001_B2010.80.000_07 21 13.00_kg_2	\
0	NaN	NaN	
1	NaN	NaN	
2	NaN	NaN	
3	NaN	NaN	
4	NaN	NaN	
5	NaN	NaN	
6	NaN	NaN	
7	NaN	NaN	
8	NaN	NaN	
9	NaN	NaN	
10	NaN	NaN	
11	NaN	NaN	
12	NaN	NaN	
13	NaN	NaN	
14	NaN	NaN	
15	NaN	NaN	
16	NaN	NaN	
17	NaN	NaN	
18	NaN	NaN	
19	NaN	NaN	
20	NaN	NaN	
21	NaN	NaN	
22	NaN	NaN	
23	NaN	NaN	
24	NaN	NaN	
25	NaN	NaN	
26	NaN	NaN	
27	NaN	NaN	
28	NaN	NaN	
29	NaN	NaN	
30	NaN	NaN	
31	NaN	NaN	
32	NaN	NaN	
33	NaN	NaN	
34	NaN	NaN	
35	NaN	NaN	
36	NaN	NaN	
37	NaN	NaN	
38	NaN	NaN	
39	NaN	NaN	
40	NaN	NaN	
41	NaN	NaN	
42	NaN	NaN	
43	NaN	NaN	
44	NaN	NaN	
45	NaN	NaN	

46	NaN	NaN
47	NaN	NaN
48	NaN	NaN
49	NaN	NaN
50	NaN	NaN
51	NaN	NaN
52	NaN	NaN
53	NaN	NaN
54	NaN	NaN
55	NaN	NaN
56	NaN	NaN
57	NaN	NaN
58	NaN	NaN
59	37.3	112.67

	001_B2010.10.000_09 24 23.00_kg_2	0B1_A5020.10.000_06 11 00.00_kg_2	\
0	NaN	NaN	
1	NaN	NaN	
2	NaN	NaN	
3	NaN	NaN	
4	NaN	NaN	
5	NaN	NaN	
6	NaN	NaN	
7	NaN	NaN	
8	NaN	NaN	
9	NaN	NaN	
10	NaN	NaN	
11	NaN	NaN	
12	NaN	NaN	
13	NaN	NaN	
14	NaN	NaN	
15	NaN	NaN	
16	NaN	NaN	
17	NaN	NaN	
18	NaN	NaN	
19	NaN	NaN	
20	NaN	NaN	
21	NaN	NaN	
22	NaN	NaN	
23	NaN	NaN	
24	NaN	NaN	
25	NaN	NaN	
26	NaN	NaN	
27	NaN	NaN	
28	NaN	NaN	
29	NaN	NaN	
30	NaN	NaN	

31	NaN	NaN
32	NaN	NaN
33	NaN	NaN
34	NaN	NaN
35	NaN	NaN
36	NaN	NaN
37	NaN	NaN
38	NaN	NaN
39	NaN	NaN
40	NaN	NaN
41	NaN	NaN
42	NaN	NaN
43	NaN	NaN
44	NaN	NaN
45	NaN	NaN
46	NaN	NaN
47	NaN	NaN
48	NaN	NaN
49	NaN	NaN
50	NaN	NaN
51	NaN	NaN
52	NaN	NaN
53	NaN	NaN
54	NaN	NaN
55	NaN	NaN
56	NaN	NaN
57	NaN	NaN
58	NaN	NaN
59	2655.54	277.59

	0B1_A5020.10.000_06 11 00.00_kg_1	0B1_A5020.10.000_09 21 16.00_kg_1	\
0	NaN	NaN	
1	NaN	NaN	
2	NaN	NaN	
3	NaN	NaN	
4	NaN	NaN	
5	NaN	NaN	
6	NaN	NaN	
7	NaN	NaN	
8	NaN	NaN	
9	NaN	NaN	
10	NaN	NaN	
11	NaN	NaN	
12	NaN	NaN	
13	NaN	NaN	
14	NaN	NaN	
15	NaN	NaN	

```
16                                    NaN                                    NaN
17                                    NaN                                    NaN
18                                    NaN                                    NaN
19                                    NaN                                    NaN
20                                    NaN                                    NaN
21                                    NaN                                    NaN
22                                    NaN                                    NaN
23                                    NaN                                    NaN
24                                    NaN                                    NaN
25                                    NaN                                    NaN
26                                    NaN                                    NaN
27                                    NaN                                    NaN
28                                    NaN                                    NaN
29                                    NaN                                    NaN
30                                    NaN                                    NaN
31                                    NaN                                    NaN
32                                    NaN                                    NaN
33                                    NaN                                    NaN
34                                    NaN                                    NaN
35                                    NaN                                    NaN
36                                    NaN                                    NaN
37                                    NaN                                    NaN
38                                    NaN                                    NaN
39                                    NaN                                    NaN
40                                    NaN                                    NaN
41                                    NaN                                    NaN
42                                    NaN                                    NaN
43                                    NaN                                    NaN
44                                    NaN                                    NaN
45                                    NaN                                    NaN
46                                    NaN                                    NaN
47                                    NaN                                    NaN
48                                    NaN                                    NaN
49                                    NaN                                    NaN
50                                    NaN                                    NaN
51                                    NaN                                    NaN
52                                    NaN                                    NaN
53                                    NaN                                    NaN
54                                    NaN                                    NaN
55                                    NaN                                    NaN
56                                    NaN                                    NaN
57                                    NaN                                    NaN
58                                    NaN                                    NaN
59                                 889.66                                 854.98

    000_C1010.10.000_07 21 13.00_kg_1  00R_B3010.90.000_07 21 13.00_kg_1  \
0                                   NaN                                    NaN
```

1	NaN	NaN
2	NaN	NaN
3	NaN	NaN
4	NaN	NaN
5	NaN	NaN
6	NaN	NaN
7	NaN	NaN
8	NaN	NaN
9	NaN	NaN
10	NaN	NaN
11	NaN	NaN
12	NaN	NaN
13	NaN	NaN
14	NaN	NaN
15	NaN	NaN
16	NaN	NaN
17	NaN	NaN
18	NaN	NaN
19	NaN	NaN
20	NaN	NaN
21	NaN	NaN
22	NaN	NaN
23	NaN	NaN
24	NaN	NaN
25	NaN	NaN
26	NaN	NaN
27	NaN	NaN
28	NaN	NaN
29	NaN	NaN
30	NaN	NaN
31	NaN	NaN
32	NaN	NaN
33	NaN	NaN
34	NaN	NaN
35	NaN	NaN
36	NaN	NaN
37	NaN	NaN
38	NaN	NaN
39	NaN	NaN
40	NaN	NaN
41	NaN	NaN
42	NaN	NaN
43	NaN	NaN
44	NaN	NaN
45	NaN	NaN
46	NaN	NaN
47	NaN	NaN

48	NaN	NaN
49	NaN	NaN
50	NaN	NaN
51	NaN	NaN
52	NaN	NaN
53	NaN	NaN
54	NaN	NaN
55	NaN	NaN
56	NaN	NaN
57	NaN	NaN
58	NaN	NaN
59	127.47	420.29

	00R_B1020.20.000_07 51 13.00_kg_1
0	NaN
1	NaN
2	NaN
3	NaN
4	NaN
5	NaN
6	NaN
7	NaN
8	NaN
9	NaN
10	NaN
11	NaN
12	NaN
13	NaN
14	NaN
15	NaN
16	NaN
17	NaN
18	NaN
19	NaN
20	NaN
21	NaN
22	NaN
23	NaN
24	NaN
25	NaN
26	NaN
27	NaN
28	NaN
29	NaN
30	NaN
31	NaN
32	NaN

```
33                                NaN
34                                NaN
35                                NaN
36                                NaN
37                                NaN
38                                NaN
39                                NaN
40                                NaN
41                                NaN
42                                NaN
43                                NaN
44                                NaN
45                                NaN
46                                NaN
47                                NaN
48                                NaN
49                                NaN
50                                NaN
51                                NaN
52                                NaN
53                                NaN
54                                NaN
55                                NaN
56                                NaN
57                                NaN
58                                NaN
59                             315.22

[60 rows x 2090 columns]
```

[5]:
```
name_conversion = pd.read_csv('name_conversion.csv')
building_name_conversion = pd.read_csv('building_type_name_conversion.csv')
```

[6]:
```
building_name_map = {k['Building Code']:k['Building Type'] for _,k in␣
↪building_name_conversion.iterrows()}
```

[7]:
```
name_map = {k.Code:k.Category for _,k in name_conversion.iterrows()}
```

[8]:
```
additional_categories_map = {v:k for k,v in {
    'Continuous Footings':'0CF',
    'Foundation Walls':'0FW',
    'Spread Footings':'0SF',
    'Column Piers':'0CP',
    'Columns Supporting Floors':'CSF',
    'Floor Girders and Beams':'FGB',
    'Floor Trusses':'0FT',
    'Floor Joists':'0FJ',
```

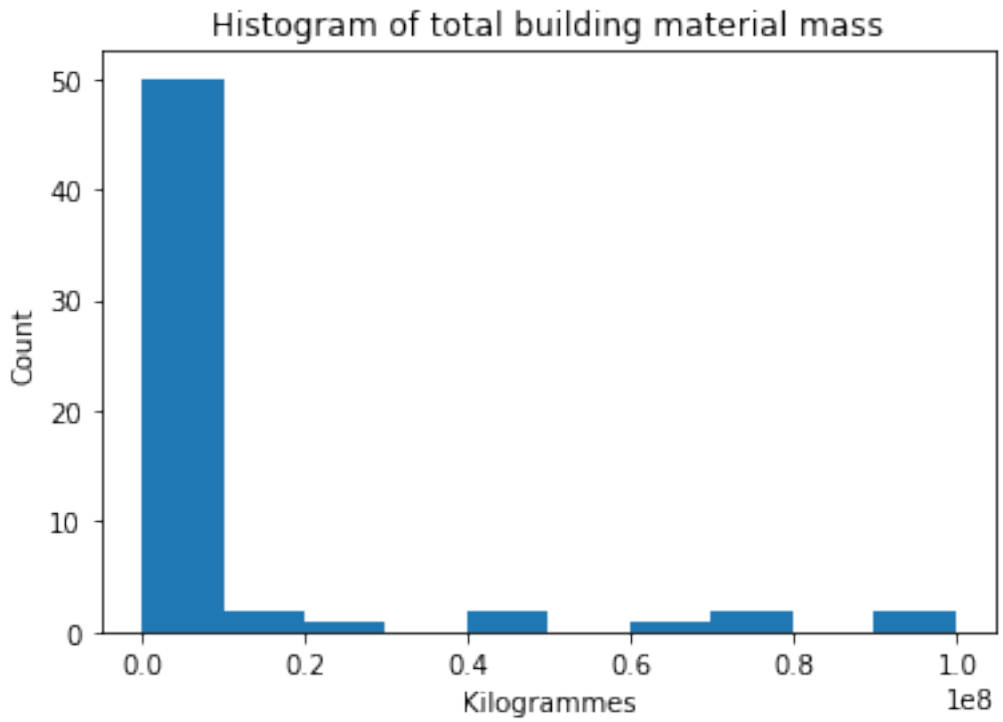
```
    'Columns Supporting Roofs':'CSR',
    'Roof Girders and Beams':'RGB',
    'Roof Trusses':'ORT',
    'Roof Joists':'ORJ',
    'Parking Bumpers':'OPB',
    'Precast Concrete Stair Treads':'PCS',
    'Roof Curbs':'ORC',
    'Exterior Wall Construction':'EWC',
    'Composite Decking':'CPD',
    'Cast-in-Place concrete':'CIC',
    'Floor Structural Frame':'FSF',
    'Associated Metal Fabrications':'AMF',
    'Floor Construction Supplementary Components':'FCS',
    'Roof Construction Supplementary Components':'RCS',
    'Residential Elevators':'ORE',
    'Vegetated Low-Slope Roofing':'VLR',
    'Swimming Pools':'SWP',
    'Excavation Soil Anchors':'ESA',
    'Floor Trusses':'FTS',
    'Roof Window and Skylight Performance':'RWS',
    'Rainwater Storage Tanks':'RST',
    'Gray Water Tanks':'GWT'}.items()
}

additional_categories_map['OFT'] = 'Floor Trusses'
```

2 1. Plot sample figures

Here we plot building material mass.

[9]:
```
plt.hist(df[[c for c in df.columns if 'kg' in c]].sum(axis=1));
plt.title('Histogram of total building material mass')
plt.xlabel('Kilogrammes')
plt.ylabel('Count');
```

[9]:
```
Text(0, 0.5, 'Count')
```



3 2. Investigate a specific material

In this example, we select only columns that match the MasterFormat code for Structural Concrete. Then, we aggregate based on Level 2 UniFormat code.

[10]:
```
cols = [d for d in df.columns if '03 31 00' in d]
```

[11]:
```
f = lambda x: re.split('[_\.\ ]',x)[1][0:3]
concrete_df = pd.concat([df[headings],df[cols].groupby(f,axis=1).sum()],axis=1).
 ↪rename(columns=name_map)
```

[12]:
```
concrete_df
```

[12]:

	Building Identifier	Country	City	Quality / Stage of Data	\
0	1	CA	TOR	00IFC	
1	2	CA	TOR	00IFC	
2	3	CA	TOR	00IFC	
3	4	CA	TOR	00IFC	
4	5	CA	TOR	00IFC	
5	6	CA	TOR	00IFC	
6	7	CA	TOR	00IFC	
7	8	CA	TOR	00IFC	
8	9	CA	TOR	00IFC	

9	10	CA	TOR	00IFC
10	11	CA	TOR	00IFC
11	12	CA	TOR	00IFC
12	13	CA	TOR	00IFC
13	14	CA	TOR	00IFC
14	15	CA	TOR	00IFC
15	16	CA	TOR	00IFC
16	17	CA	TOR	00IFC
17	18	CA	TOR	00IFC
18	19	CA	TOR	00IFC
19	20	CA	TOR	00IFC
20	21	CA	TOR	00IFC
21	22	CA	TOR	00IFC
22	23	CA	TOR	00IFC
23	24	CA	TOR	00IFC
24	25	CA	TOR	00IFC
25	26	CA	TOR	00IFC
26	27	CA	WIN	00IFC
27	28	CA	TOR	00IFC
28	29	CA	TOR	00IFC
29	30	CA	TOR	00IFC
30	31	CA	TOR	00IFC
31	32	CA	TOR	00IFC
32	33	CA	TOR	00IFC
33	34	CA	TOR	00IFC
34	35	CA	TOR	00IFC
35	36	CA	TOR	00IFC
36	37	CA	TOR	00IFC
37	38	CA	TOR	00IFC
38	39	CA	TOR	00IFC
39	40	US	NEW	00IFC
40	41	CA	TOR	00IFC
41	42	CA	TOR	00IFC
42	43	CA	TOR	00IFC
43	44	CA	TOR	00IFC
44	45	CA	TOR	00IFC
45	46	CA	TOR	00IFC
46	47	CA	TOR	00IFC
47	48	CA	RIC	0IARC
48	49	CA	TOR	00IFC
49	50	CA	TOR	00IFC
50	51	CA	TOR	00IFC
51	52	CA	TOR	00IFC
52	53	CA	TOR	00IFC
53	54	CA	TOR	00IFC
54	55	CA	TOR	00IFC
55	56	CA	TOR	00IFC

56	57	CA	TOR	00IFC
57	58	CA	TOR	00IFC
58	59	CA	TOR	0IFBP
59	60	CA	TOR	0IFBP

	Construction Date	Building Type	Gross Floor Area	Foundations	\
0	2021	SND	521.18	1.709236e+05	
1	2021	SND	389.24	1.082862e+05	
2	2021	SND	411.64	1.909299e+05	
3	2021	SND	269.56	6.736923e+04	
4	2011	OFF	11248.00	0.000000e+00	
5	2011	APB	11317.00	0.000000e+00	
6	2021	SND	445.99	1.295202e+05	
7	2021	SND	438.45	1.174431e+05	
8	2021	SND	714.07	1.927680e+05	
9	2021	SND	343.24	9.564723e+04	
10	2009	OFF	73083.00	0.000000e+00	
11	1917	SMR	199.93	9.927316e+04	
12	2021	SND	226.89	5.835472e+04	
13	2021	SND	611.73	2.061282e+05	
14	2021	SND	343.44	1.436814e+05	
15	2021	SND	613.38	1.789777e+05	
16	1969	SNR	413.72	9.293583e+04	
17	1969	SNR	333.49	1.186380e+05	
18	2021	SND	178.38	6.408230e+04	
19	2021	SND	323.80	4.733438e+04	
20	2020	SND	837.56	2.605656e+05	
21	2021	SND	587.86	2.455371e+05	
22	2021	SND	568.21	1.415184e+05	
23	2021	SMD	234.73	8.560216e+04	
24	2021	SND	294.84	7.580863e+04	
25	2021	SND	496.77	1.205336e+05	
26	2007	OFF	73600.00	0.000000e+00	
27	2021	SND	643.30	9.718853e+04	
28	2021	SND	701.61	1.810933e+05	
29	2021	SMD	257.75	8.183304e+04	
30	2021	SND	378.70	1.477228e+05	
31	2021	SND	324.16	1.188635e+05	
32	2020	SND	533.53	1.627046e+05	
33	2020	SMD	254.05	8.882102e+04	
34	2021	SND	423.03	9.980270e+04	
35	2021	SND	328.16	1.238544e+05	
36	2021	SND	421.59	1.760423e+05	
37	2020	SND	628.59	2.298828e+05	
38	2021	SND	464.51	1.886381e+05	
39	2017	EDU	8983.00	0.000000e+00	
40	2021	SND	346.14	9.748630e+04	

41	1913	SNR	161.08	5.362299e+04
42	2021	SND	891.97	2.157609e+05
43	2021	SND	525.61	2.567725e+05
44	2021	SND	502.87	1.372402e+05
45	2021	SND	379.18	1.437386e+05
46	2021	SND	549.65	1.435894e+05
47	2016	EDU	6819.00	0.000000e+00
48	2020	SND	393.82	7.294707e+04
49	2021	SND	648.14	2.216331e+05
50	1988	INS	21934.00	0.000000e+00
51	2018	APB	53146.02	1.115822e+07
52	2018	MIX	33975.25	4.220040e+06
53	2017	APB	69784.00	7.912944e+06
54	2017	APB	39409.04	9.350736e+06
55	2016	APB	53871.00	1.627512e+06
56	2020	LNW	137.23	3.111394e+04
57	2020	LNW	144.92	3.241172e+04
58	2019	LNW	83.10	3.347723e+04
59	2021	LNW	234.79	8.400714e+04

	Subgrade Enclosures	Slabs-On-Grade	Substructure	Interior	\
0	0.0	6.721219e+04		0.0	
1	0.0	3.576043e+04		0.0	
2	0.0	3.246461e+04		0.0	
3	0.0	1.595211e+04		0.0	
4	0.0	0.000000e+00		0.0	
5	0.0	0.000000e+00		0.0	
6	0.0	3.521918e+04		0.0	
7	0.0	4.289057e+04		0.0	
8	0.0	8.446873e+04		0.0	
9	0.0	2.033114e+04		0.0	
10	0.0	0.000000e+00		0.0	
11	0.0	1.971760e+04		0.0	
12	0.0	1.435987e+04		0.0	
13	0.0	4.140039e+04		0.0	
14	0.0	2.246836e+04		0.0	
15	0.0	4.219445e+04		0.0	
16	0.0	3.376814e+04		0.0	
17	0.0	2.622366e+04		0.0	
18	0.0	2.343862e+04		0.0	
19	0.0	2.368485e+04		0.0	
20	0.0	6.344851e+04		0.0	
21	0.0	6.865710e+04		0.0	
22	0.0	6.684690e+04		0.0	
23	0.0	1.294360e+04		0.0	
24	0.0	1.791821e+04		0.0	
25	0.0	5.137996e+04		0.0	

26	0.0	0.000000e+00	0.0
27	0.0	5.230228e+04	0.0
28	0.0	6.233222e+04	0.0
29	0.0	1.211886e+04	0.0
30	0.0	3.514722e+04	0.0
31	0.0	2.011968e+04	0.0
32	0.0	3.674638e+04	0.0
33	0.0	1.160387e+04	0.0
34	0.0	3.329286e+04	0.0
35	0.0	1.931159e+04	0.0
36	0.0	3.304437e+04	0.0
37	0.0	5.528816e+04	0.0
38	0.0	2.866777e+04	0.0
39	0.0	0.000000e+00	0.0
40	0.0	2.237098e+04	0.0
41	0.0	1.235658e+04	0.0
42	0.0	5.949332e+04	0.0
43	0.0	3.378685e+04	0.0
44	0.0	3.951047e+04	0.0
45	0.0	2.913799e+04	0.0
46	0.0	3.506390e+04	0.0
47	0.0	0.000000e+00	0.0
48	0.0	3.364275e+04	0.0
49	0.0	6.099032e+04	0.0
50	0.0	0.000000e+00	0.0
51	2728008.0	3.647520e+05	11033448.0
52	1705680.0	3.834720e+05	5400288.0
53	3246168.0	1.407000e+06	14052000.0
54	3567720.0	9.045840e+05	7607280.0
55	3438168.0	7.174800e+05	22907184.0
56	0.0	1.439848e+04	0.0
57	0.0	2.000253e+04	0.0
58	0.0	5.412759e+03	0.0
59	0.0	1.962799e+04	0.0

	Substructure Related Activities	Superstructure	\
0	0.0	1.938810e+03	
1	0.0	1.397610e+03	
2	0.0	1.528710e+02	
3	0.0	1.212090e+01	
4	0.0	0.000000e+00	
5	0.0	0.000000e+00	
6	0.0	5.332590e+02	
7	0.0	1.970790e+03	
8	0.0	4.049670e+03	
9	0.0	9.440170e+02	
10	0.0	0.000000e+00	

11	0.0	0.000000e+00
12	0.0	9.785830e+02
13	0.0	5.381500e+02
14	0.0	0.000000e+00
15	0.0	0.000000e+00
16	0.0	0.000000e+00
17	0.0	7.514840e+03
18	0.0	0.000000e+00
19	0.0	2.111800e+03
20	0.0	3.270810e+03
21	0.0	2.533580e+03
22	0.0	6.016340e+02
23	0.0	1.827610e+03
24	0.0	5.977480e+02
25	0.0	2.540900e+03
26	0.0	0.000000e+00
27	0.0	7.189470e+02
28	0.0	2.276420e+02
29	0.0	1.587900e+03
30	0.0	1.096510e+04
31	0.0	5.530400e+03
32	0.0	1.360980e+03
33	0.0	2.177290e+03
34	0.0	6.524310e+02
35	0.0	3.944150e+03
36	0.0	4.401230e+02
37	0.0	8.518740e+02
38	0.0	2.593160e+03
39	0.0	0.000000e+00
40	0.0	2.360810e+02
41	0.0	0.000000e+00
42	0.0	8.599660e+02
43	0.0	1.038810e+03
44	0.0	4.881840e+02
45	0.0	1.267510e+03
46	0.0	1.154890e+03
47	0.0	0.000000e+00
48	0.0	1.835120e+02
49	0.0	1.041320e+03
50	0.0	0.000000e+00
51	133464.0	2.780006e+07
52	112872.0	2.226535e+07
53	169896.0	3.204622e+07
54	276264.0	1.483577e+07
55	93048.0	3.239134e+07
56	0.0	0.000000e+00
57	0.0	0.000000e+00

58	0.0	0.000000e+00
59	0.0	0.000000e+00

	Exterior Vertical Enclosures	Exterior Horizontal Enclosures	\
0	0.0	0.0	
1	0.0	0.0	
2	0.0	0.0	
3	0.0	0.0	
4	0.0	0.0	
5	0.0	0.0	
6	0.0	0.0	
7	0.0	0.0	
8	0.0	0.0	
9	0.0	0.0	
10	0.0	0.0	
11	0.0	0.0	
12	0.0	0.0	
13	0.0	0.0	
14	0.0	0.0	
15	0.0	0.0	
16	0.0	0.0	
17	0.0	0.0	
18	0.0	0.0	
19	0.0	0.0	
20	0.0	0.0	
21	0.0	0.0	
22	0.0	0.0	
23	0.0	0.0	
24	0.0	0.0	
25	0.0	0.0	
26	0.0	0.0	
27	0.0	0.0	
28	0.0	0.0	
29	0.0	0.0	
30	0.0	0.0	
31	0.0	0.0	
32	0.0	0.0	
33	0.0	0.0	
34	0.0	0.0	
35	0.0	0.0	
36	0.0	0.0	
37	0.0	0.0	
38	0.0	0.0	
39	0.0	0.0	
40	0.0	0.0	
41	0.0	0.0	
42	0.0	0.0	

43	0.0	0.0
44	0.0	0.0
45	0.0	0.0
46	0.0	0.0
47	0.0	0.0
48	0.0	0.0
49	0.0	0.0
50	0.0	0.0
51	727896.0	537984.0
52	405408.0	392400.0
53	328032.0	799872.0
54	119088.0	0.0
55	159336.0	0.0
56	0.0	0.0
57	0.0	0.0
58	0.0	0.0
59	0.0	0.0

	Interior Construction	Conveying	Plumbing	Special Construction	\
0	0.0	0.0	0.0	0.0	
1	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.0	
8	11307.2	0.0	0.0	0.0	
9	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.0	
13	0.0	0.0	0.0	0.0	
14	0.0	0.0	0.0	0.0	
15	0.0	0.0	0.0	0.0	
16	0.0	0.0	0.0	0.0	
17	0.0	0.0	0.0	0.0	
18	0.0	0.0	0.0	0.0	
19	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.0	0.0	
21	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	0.0	
23	0.0	0.0	0.0	0.0	
24	0.0	0.0	0.0	0.0	
25	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.0	0.0	

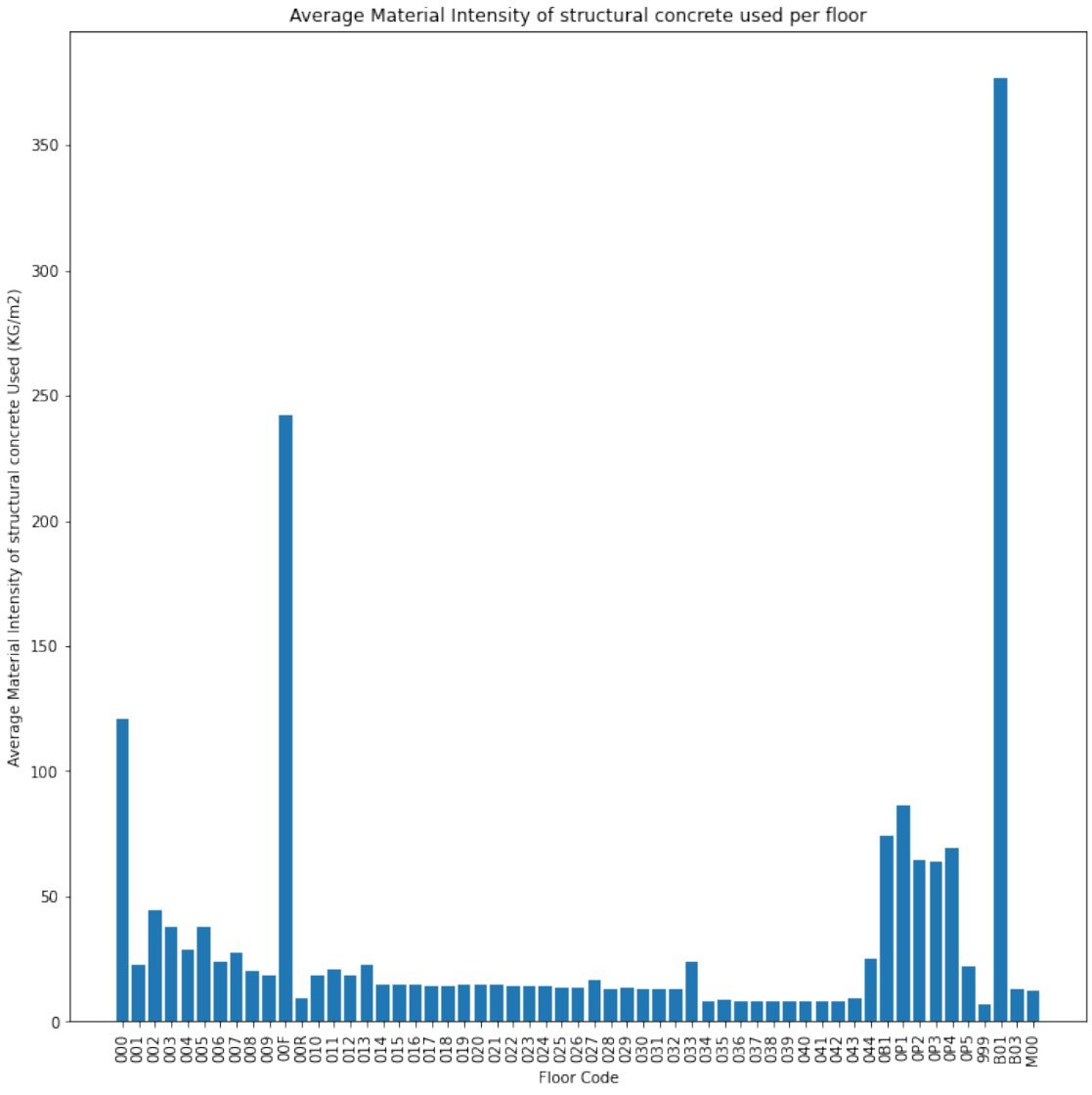
28	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0
51	6816696.0	2494560.0	0.0	80592.0
52	5893176.0	1829328.0	48816.0	62280.0
53	9050592.0	2304480.0	172032.0	0.0
54	5180976.0	861888.0	130152.0	0.0
55	5604960.0	1664448.0	0.0	220992.0
56	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0
58	0.0	0.0	0.0	0.0
59	0.0	0.0	0.0	0.0

	Site Improvements
0	0.0
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6	0.0
7	0.0
8	0.0
9	0.0
10	0.0
11	0.0
12	0.0

13	0.0
14	0.0
15	0.0
16	0.0
17	0.0
18	0.0
19	0.0
20	0.0
21	0.0
22	0.0
23	0.0
24	0.0
25	0.0
26	0.0
27	0.0
28	0.0
29	0.0
30	0.0
31	0.0
32	0.0
33	0.0
34	0.0
35	0.0
36	0.0
37	0.0
38	0.0
39	0.0
40	0.0
41	0.0
42	0.0
43	0.0
44	0.0
45	0.0
46	0.0
47	0.0
48	0.0
49	0.0
50	0.0
51	0.0
52	0.0
53	18384.0
54	97560.0
55	0.0
56	0.0
57	0.0
58	0.0
59	0.0

[13]:
```
grouping_function = lambda x: x.split('_')[0] #This function takes in a full␣
↪column name, like "000_G2010.20.000_03 00 00.00_m3_1", and returns only the␣
↪floor.
to_draw = df[cols].groupby(grouping_function,axis=1).sum().replace(0,np.NaN).
↪div(df['Gross Floor Area'],axis='rows').mean()
plt.figure(figsize=(12,12))
plt.bar(to_draw.keys(), to_draw.values)
plt.xticks(rotation=90)
plt.title('Average Material Intensity of structural concrete used per floor')
plt.ylabel('Average Material Intensity of structural concrete Used (KG/m2)')
plt.xlabel('Floor Code');
```

[13]: Text(0.5, 0, 'Floor Code')



Now, we will aggregate to Level 3 MasterFormat codes, and display these values for the first three entries.

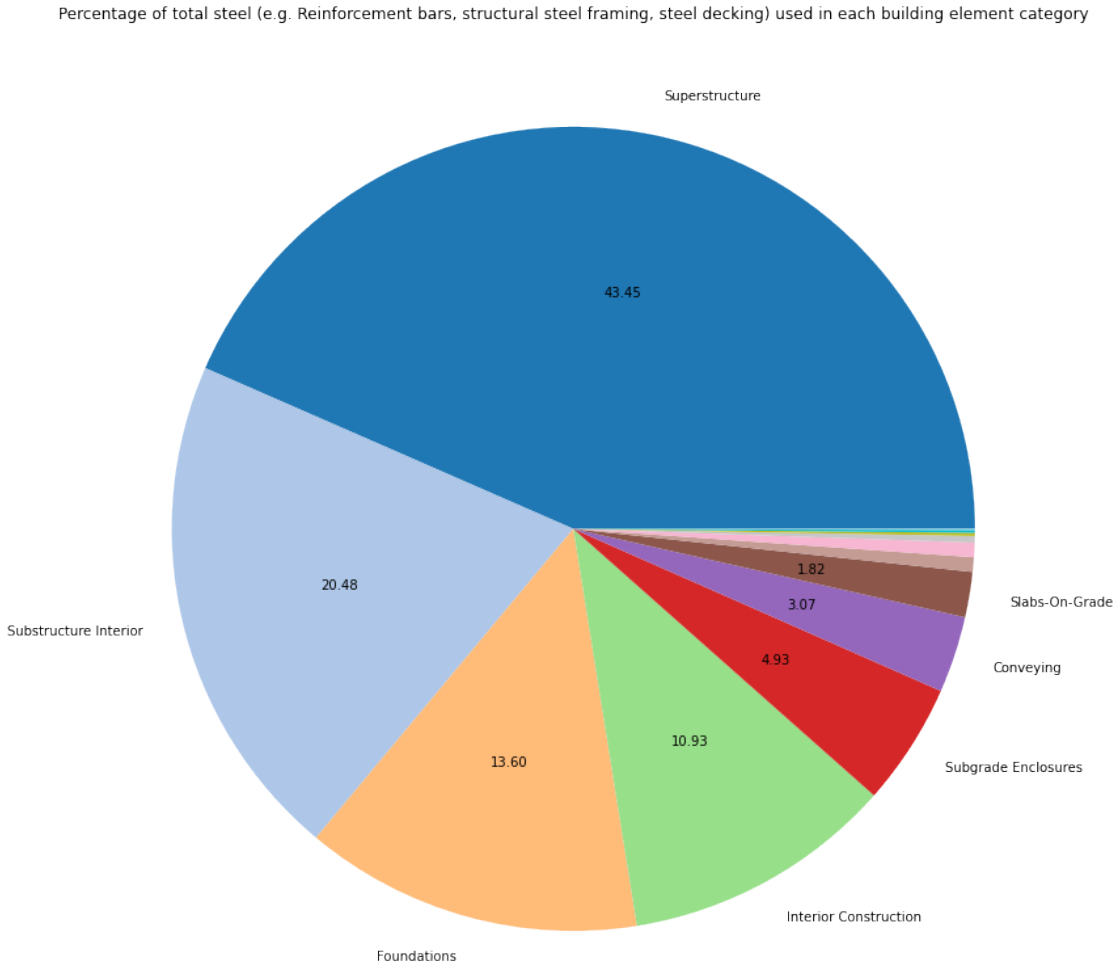
[14]:
```
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0:3]] #This function takes in a␣
 ↪full column name and returns only the Level 3 MasterFormat code.
concrete_df = df[cols].groupby(f,axis=1).sum()
```

[15]:
```
concrete_df.mean().sort_values(ascending=False)
```

[15]:
```
Superstructure                    2.156826e+06
Substructure Interior             1.016670e+06
Foundations                       6.750260e+05
Interior Construction             5.426285e+05
Subgrade Enclosures               2.447624e+05
Conveying                         1.525784e+05
Slabs-On-Grade                    9.043012e+04
Exterior Vertical Enclosures      2.899600e+04
Exterior Horizontal Enclosures    2.883760e+04
Substructure Related Activities   1.309240e+04
Special Construction              6.064400e+03
Plumbing                          5.850000e+03
Site Improvements                 1.932400e+03
dtype: float64
```

3.1 Pie chart version A: on-pie chart labels for all $> 1\%$

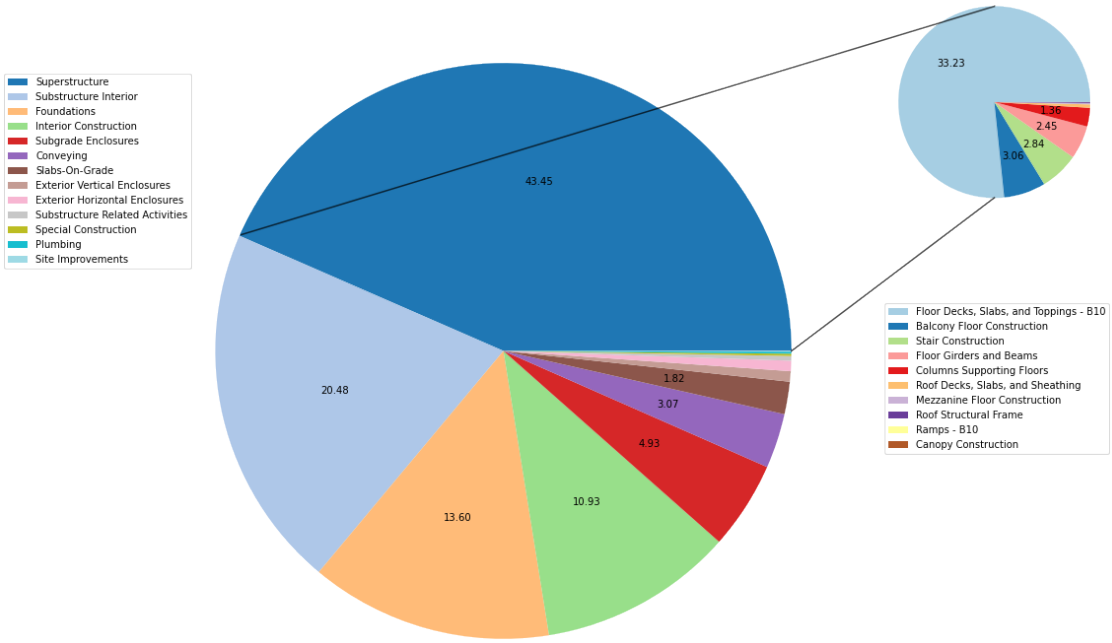
[16]:
```
def my_autopct(pct):
    return ('%.2f' % pct) if pct > 1 else ''
to_plot = concrete_df.mean().sort_values(ascending=False)
to_plot.plot.pie(figsize=(12,12),colormap='tab20',autopct=my_autopct,labels=[k␣
 ↪if v > 30000 else '' for k,v in to_plot.items()])
plt.ylabel('')
plt.title('Percentage of total steel (e.g. Reinforcement bars, structural steel␣
 ↪framing, steel decking) used in each building element category');
# plt.legend(loc='center left',bbox_to_anchor=(-0.20, 0.75));
plt.tight_layout();
```



3.2 Pie version B: external legend with slice labels

[17]:
```
fig = plt.figure(figsize=(16,12))
gs = gridspec.GridSpec(2, 2, width_ratios=[3, 1])
ax0 = plt.subplot(gs[:,0])

def my_autopct(pct):
    return ('%.2f' % pct) if pct > 1 else ''
to_plot = concrete_df.mean().sort_values(ascending=False)
to_plot.plot.pie(ax=ax0,colormap='tab20',autopct=my_autopct,labeldistance=None)
plt.ylabel('')
plt.legend(loc='center left',bbox_to_anchor=(-0.20, 0.75));
plt.tight_layout();

ax1 = plt.subplot(gs[0,1])
```

```
f = lambda x: \
    additional_categories_map[re.split('[_\.\ ]',x)[3]] \
    if \
    re.split('[_\.\ ]',x)[3] != '000' \
    else \
    name_map['.'.join(re.split('[_\.\ ]',x)[1:3])]

superstructure_df = df[[c for c in cols if 'B10' in c]].groupby(f,axis=1).sum()
to_plot = superstructure_df.mean().sort_values(ascending=False)
def my_autopct(pct):
    return ('%.2f' % ((pct * 0.4335))) if pct > 1 else ''
to_plot.plot.pie(ax=ax1,colormap='Paired',autopct=my_autopct,labeldistance=None)
plt.ylabel('')
plt.legend(loc='center right',bbox_to_anchor=(1, -0.65));
plt.tight_layout();

transFigure = fig.transFigure.inverted()

coord1a = transFigure.transform(ax0.transData.transform([1,0]))
coord2a = transFigure.transform(ax1.transData.transform([0,-0.72]))

coord1b = transFigure.transform(ax0.transData.transform([-0.91,0.35]))
coord2b = transFigure.transform(ax1.transData.transform([0,0.72]))

linea = matplotlib.lines.Line2D((coord1a[0],coord2a[0]),(coord1a[1],coord2a[1]),
                                transform=fig.transFigure,c='black',alpha=0.7)
lineb = matplotlib.lines.Line2D((coord1b[0],coord2b[0]),(coord1b[1],coord2b[1]),
                                 transform=fig.transFigure,c='black',alpha=0.7)
fig.lines = linea,lineb,

plt.savefig('concrete_breakdown_pie.pdf')
```



We can produce a pie chart for a single building, also.

[18]:
```
mf_codes = pd.read_csv('mf_name_conversion.csv')
```

[19]:
```
tofind = [
    'Plain Steel Reinforcement Bars',
    'Reinforcement Bars',
    'Structural Steel Framing',
    'Fabric and Grid Reinforcing',
    'Metal Doors',
    'Metal Roof Panel',
    'Metal Stairs',
    'Metal Railings',
    'Steel Decking',
    'Steel Joist Framing',
    'Steel'
] #List of terms we are looking to identify in column names.

tokeep = [
    c for c in mf_codes.Title.values if any(t in c for t in tofind)
] #For each codes' corresponding in MasterFormat

steel_codes = mf_codes[mf_codes.Title.isin(tokeep)]
```

[20]:
```
columns_to_keep = []
for column in df.columns:
    if 'kg' in column:
        code = re.split('_',column)[2]
        for k,c in steel_codes.values:
            if c in code:
                columns_to_keep.append(column)
```

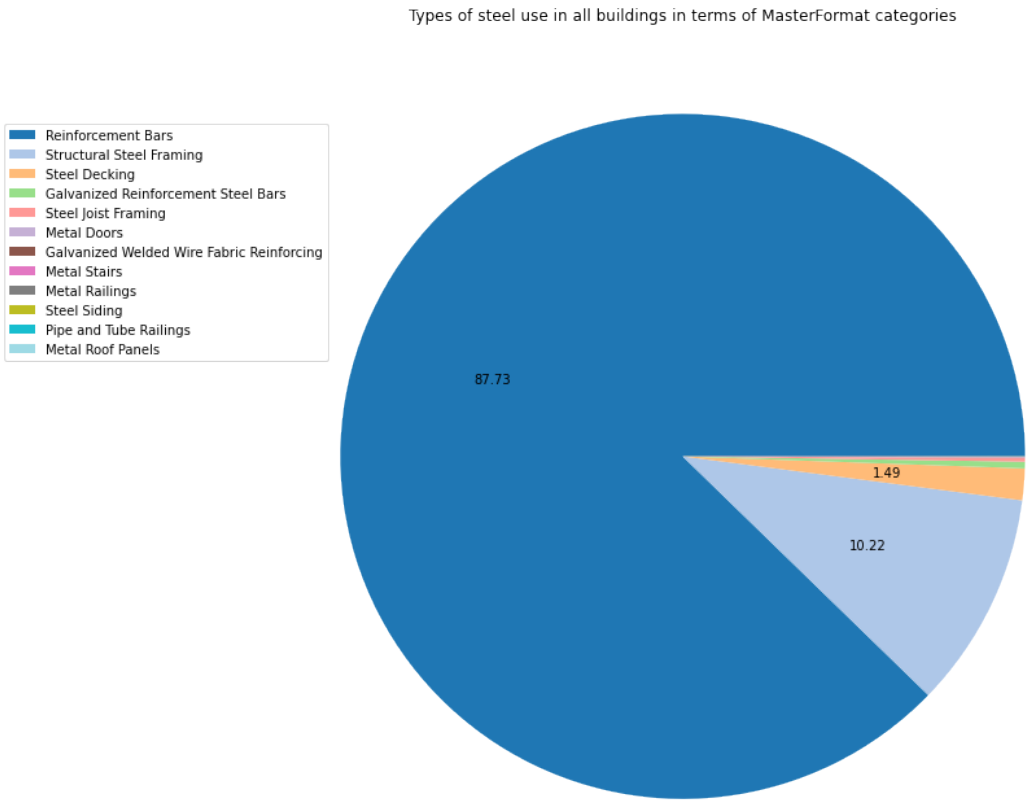
[21]:
```
f = lambda x: mf_codes[mf_codes.Code == str.replace(re.split('_',x)[2],'00','').
 ↪strip('.')].values[0][0]
steel_df = df[columns_to_keep].groupby(f,axis=1).sum()
```

[22]:
```
(steel_df>0).sum(axis=1).sort_values()
```

[22]:
```
15    1
42    1
22    1
36    1
7     1
34    1
31    1
35    1
55    2
58    2
40    2
41    2
1     2
43    2
24    2
23    2
21    2
20    2
54    2
44    2
17    2
16    2
30    2
14    2
45    2
12    2
11    2
32    2
9     2
33    2
3     2
18    2
0     3
```

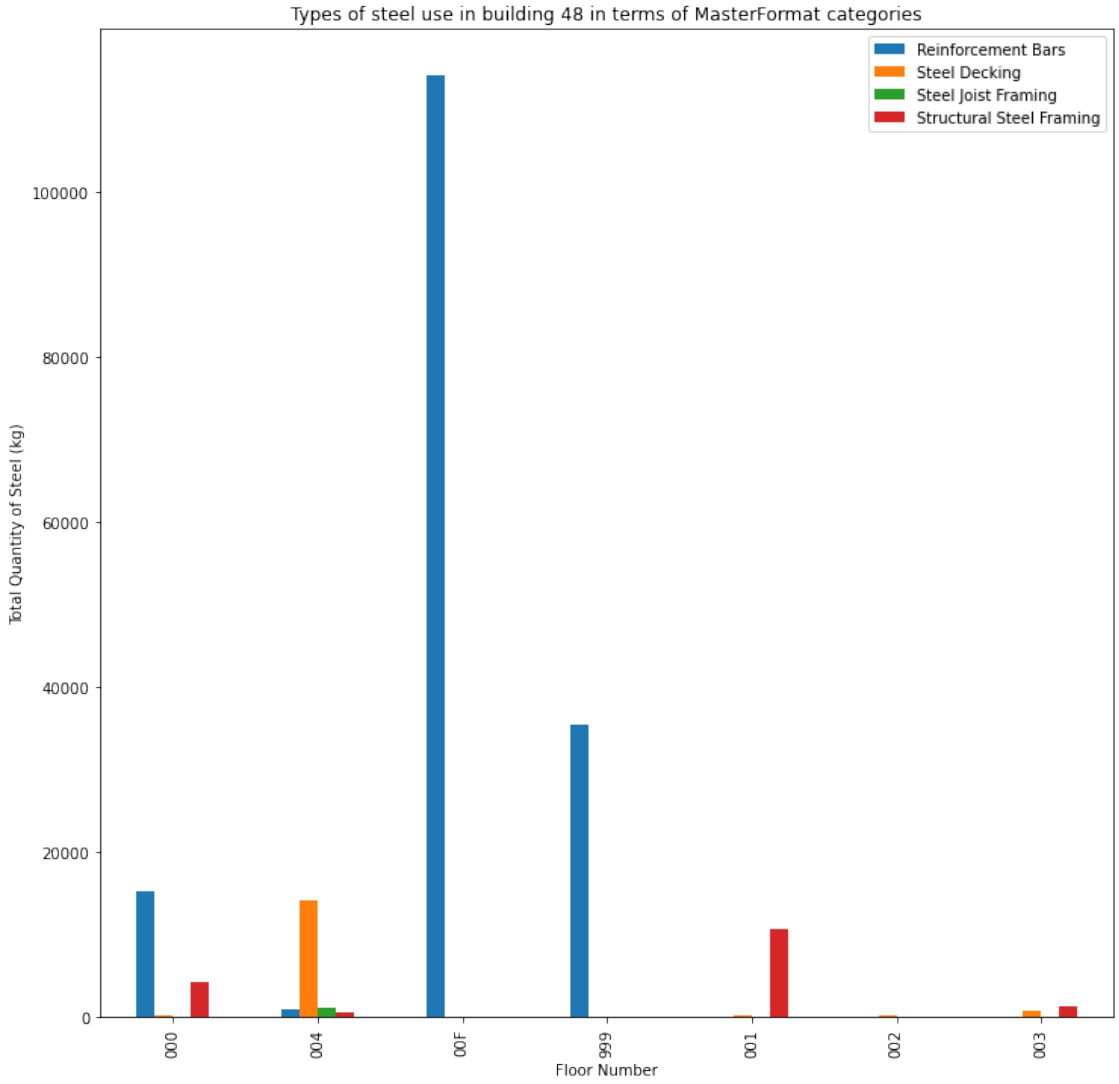
```
52    3
53    3
56    3
46    3
39    3
29    3
37    3
28    3
27    3
26    3
25    3
13    3
10    3
2     3
38    3
5     3
6     3
8     3
57    4
4     4
49    4
50    4
48    4
47    4
19    4
51    4
59    4
dtype: int64
```

[23]:
```
def my_autopct(pct):
    return ('%.2f' % (pct)) if pct > 1 else ''
to_plot = steel_df.sum().sort_values(ascending=False)
to_plot.plot.
 ↪pie(figsize=(12,12),colormap='tab20',autopct=my_autopct,labeldistance=None)
plt.legend(loc='center left',bbox_to_anchor=(-0.30, 0.75));

plt.ylabel('')
plt.title(f'Types of steel use in all buildings in terms of MasterFormat␣
 ↪categories');
plt.tight_layout();

plt.savefig('steel_composition_pie.pdf')
```



[24]:
```
f = lambda x: mf_codes[mf_codes.Code == str.replace(re.split('_',x)[2],'00','').
 ↪strip('.')].values[0][0] + '/' + x.split('_')[0]
tdf = df[columns_to_keep].groupby(f,axis=1).sum().iloc[47,:]
tdf = tdf[tdf>0]
```

[25]:
```
from collections import defaultdict
todf = defaultdict(dict)
for (a,b),c in zip(tdf.keys().str.split('/'),tdf.values):
    todf[a][b] = c
toplot = pd.DataFrame(todf)
toplot.plot.bar(figsize=(12,12));
plt.xlabel('Floor Number')
plt.ylabel('Total Quantity of Steel (kg)')
plt.title('Types of steel use in building 48 in terms of MasterFormat␣
 ↪categories')
plt.savefig('bar_steel_onebuildingtype_byfloor.pdf')
```



We can also calculate the average for each Level 3 MasterFormat code by year of construction:

[26]:
```
concrete_df = pd.concat([df[headings[1:]],df[cols].groupby(f,axis=1).
↪sum()],axis=1)
concrete_df.groupby('Construction Date').mean()
```

[26]:

Construction Date	Gross Floor Area	Structural Concrete/000	\
1913	161.080000	0.000000e+00	
1917	199.930000	0.000000e+00	
1969	373.605000	0.000000e+00	
1988	21934.000000	0.000000e+00	
2007	73600.000000	0.000000e+00	
2009	73083.000000	0.000000e+00	

2011	11282.500000	0.000000e+00
2016	30345.000000	3.595656e+06
2017	39392.013333	4.084352e+06
2018	43560.635000	5.893680e+06
2019	83.100000	0.000000e+00
2020	418.528571	4.914431e+03
2021	445.404444	0.000000e+00

Construction Date	Structural Concrete/001	Structural Concrete/002	\
1913	1944.380000	0.0	
1917	4972.300000	0.0	
1969	7262.220500	0.0	
1988	0.000000	0.0	
2007	0.000000	0.0	
2009	0.000000	0.0	
2011	0.000000	0.0	
2016	0.000000	2680512.0	
2017	0.000000	989280.0	
2018	0.000000	1511892.0	
2019	0.000000	0.0	
2020	4923.690714	0.0	
2021	11399.123858	0.0	

Construction Date	Structural Concrete/003	Structural Concrete/004	\
1913	0.0	0.0	
1917	0.0	0.0	
1969	0.0	0.0	
1988	0.0	0.0	
2007	0.0	0.0	
2009	0.0	0.0	
2011	0.0	0.0	
2016	1686228.0	1057032.0	
2017	1232336.0	778480.0	
2018	1347936.0	1323132.0	
2019	0.0	0.0	
2020	0.0	0.0	
2021	0.0	0.0	

Construction Date	Structural Concrete/005	Structural Concrete/006	\
1913	0.0	0.0	
1917	0.0	0.0	
1969	0.0	0.0	
1988	0.0	0.0	
2007	0.0	0.0	

2009	0.0	0.0	
2011	0.0	0.0	
2016	1056780.0	1129680.0	
2017	683496.0	679376.0	
2018	2164812.0	969060.0	
2019	0.0	0.0	
2020	0.0	0.0	
2021	0.0	0.0	

	Structural Concrete/007	Structural Concrete/008	…	\
Construction Date			…	
1913	0.0	0.0	…	
1917	0.0	0.0	…	
1969	0.0	0.0	…	
1988	0.0	0.0	…	
2007	0.0	0.0	…	
2009	0.0	0.0	…	
2011	0.0	0.0	…	
2016	1809852.0	857976.0	…	
2017	632520.0	651080.0	…	
2018	752208.0	734688.0	…	
2019	0.0	0.0	…	
2020	0.0	0.0	…	
2021	0.0	0.0	…	

	Structural Concrete/0B1	Structural Concrete/0P1	\
Construction Date			
1913	0.000000	0.0	
1917	0.000000	0.0	
1969	0.000000	0.0	
1988	0.000000	0.0	
2007	0.000000	0.0	
2009	0.000000	0.0	
2011	0.000000	0.0	
2016	0.000000	2206668.0	
2017	0.000000	3402456.0	
2018	0.000000	3713916.0	
2019	5412.758585	0.0	
2020	0.000000	0.0	
2021	545.221944	0.0	

	Structural Concrete/0P2	Structural Concrete/0P3	\
Construction Date			
1913	0.0	0.0	
1917	0.0	0.0	
1969	0.0	0.0	
1988	0.0	0.0	

2007	0.0	0.0
2009	0.0	0.0
2011	0.0	0.0
2016	1715028.0	1596444.0
2017	2513320.0	2469984.0
2018	2637060.0	2756916.0
2019	0.0	0.0
2020	0.0	0.0
2021	0.0	0.0

Construction Date	Structural Concrete/0P4	Structural Concrete/0P5	\
1913	0.0	0.0	
1917	0.0	0.0	
1969	0.0	0.0	
1988	0.0	0.0	
2007	0.0	0.0	
2009	0.0	0.0	
2011	0.0	0.0	
2016	0.0	0.0	
2017	1895672.0	508328.0	
2018	4093284.0	0.0	
2019	0.0	0.0	
2020	0.0	0.0	
2021	0.0	0.0	

Construction Date	Structural Concrete/999	Structural Concrete/B01	\
1913	0.0	64035.190000	
1917	0.0	114018.460000	
1969	0.0	132278.015000	
1988	0.0	0.000000	
2007	0.0	0.000000	
2009	0.0	0.000000	
2011	0.0	0.000000	
2016	155076.0	0.000000	
2017	7736.0	0.000000	
2018	558516.0	0.000000	
2019	0.0	0.000000	
2020	0.0	140301.728571	
2021	0.0	161741.376806	

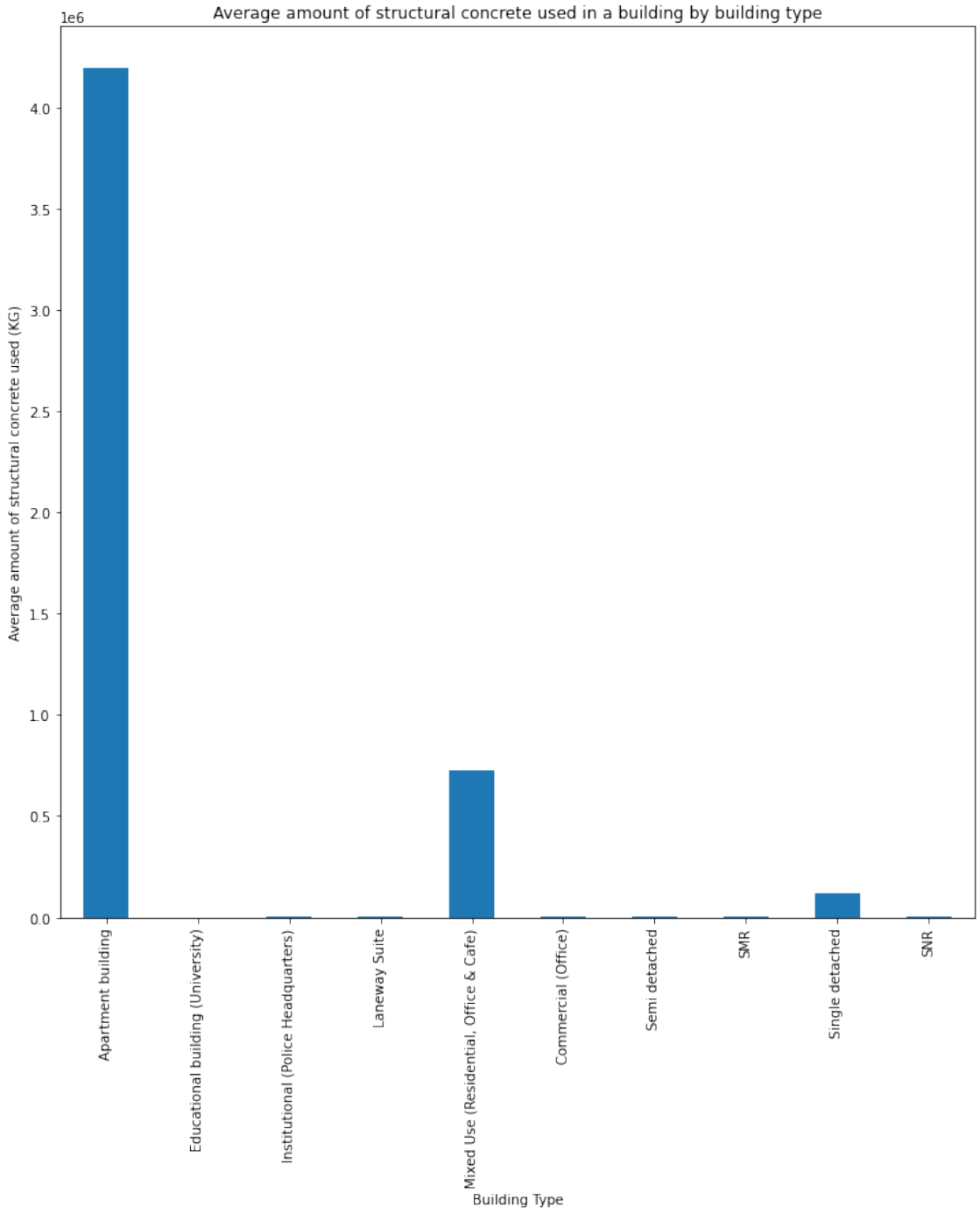
Construction Date	Structural Concrete/B03	Structural Concrete/M00
1913	0.000000	0.0
1917	0.000000	0.0
1969	0.000000	0.0

```
1988                    0.000000                    0.0
2007                    0.000000                    0.0
2009                    0.000000                    0.0
2011                    0.000000                    0.0
2016                    0.000000                82056.0
2017                    0.000000                    0.0
2018                    0.000000               597624.0
2019                    0.000000                    0.0
2020                  988.177143                    0.0
2021                    0.000000                    0.0

[13 rows x 58 columns]
```

We can get the average amount of steel in KG used per building type:

[27]:
```
concrete_df.groupby('Building Type').sum().mean(axis=1).
 ↪rename(index=building_name_map).plot(kind='bar',figsize=(12,12))
plt.ylabel('Average amount of structural concrete used (KG)')
plt.title('Average amount of structural concrete used in a building by building␣
 ↪type');
```

[27]:
```
Text(0.5, 1.0, 'Average amount of structural concrete used in a building by
building type')
```



4 3. Uncertainty by Building Type

In this section, we look at the uncertainty score associated with each material takeoff. We collect these by building type and then report the number of each value per type of building.

[28]:
```
uncertainty_level = {}
for k,v in df.iterrows():
    #Initialise empty lists for each building type as they occur
    if v['Building Type'] not in uncertainty_level.keys():
        uncertainty_level[v['Building Type']] = []
    #Append the uncertainty value for each column that is non-NaN
    for key in v[~v.isna()].keys()[7:]:
        uncertainty_level[v['Building Type']].append(key.split('_')[-1])
```

[29]:
```
from collections import Counter
```

[30]:
```
for k,v in uncertainty_level.items():
    uncertainty_level[k] = Counter(v) #Construct a Counter object per building␣
 ↪type
```

[31]:
```
uncertainty_level
```

[31]:
```
{'SND': Counter({'1': 1662, '2': 641, '4': 293}),
 'OFF': Counter({'1': 494, '3': 307}),
 'APB': Counter({'1': 1171, '2': 1, '3': 971}),
 'SMR': Counter({'1': 21, '2': 27, '4': 8}),
 'SNR': Counter({'1': 58, '2': 70, '4': 56}),
 'SMD': Counter({'1': 170, '2': 34, '4': 19}),
 'EDU': Counter({'1': 93, '3': 24, '2': 6}),
 'INS': Counter({'1': 90, '3': 77, '2': 1}),
 'MIX': Counter({'1': 363, '3': 276}),
 'LNW': Counter({'2': 46, '1': 142, '4': 19})}
```

Next, we aggregate columns by the purporse of the material and uncertainty combined, and report the average by building type.

[32]:
```
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0]] + '/' + x.split('_')[-1].
 ↪split('.')[0] #From a full code, return only the use code and uncertainty␣
 ↪score.
by_function_df = pd.concat([df[headings[1:]],df[cols].groupby(f,axis=1).
 ↪sum()],axis=1)
```

[33]:
```
by_function_df.groupby('Building Type').mean().rename(index=building_name_map).
 ↪drop(['Construction Date'],axis=1).round(2)
```

[33]:

Building Type	Gross Floor Area	Interiors/1
Apartment building	45505.41	5330644.8
Educational building (University)	7901.00	0.0
Institutional (Police Headquarters)	21934.00	0.0
Laneway Suite	150.01	0.0
Mixed Use (Residential, Office & Cafe)	33975.25	5893176.0

Commercial (Office)	52643.67	0.0
Semi detached	248.84	0.0
SMR	199.93	0.0
Single detached	478.40	305.6
SNR	302.76	0.0

Building Type	Services/1	Shell/1	Shell/2 \
Apartment building	1525512.0	21949118.40	0.00
Educational building (University)	0.0	0.00	0.00
Institutional (Police Headquarters)	0.0	0.00	0.00
Laneway Suite	0.0	0.00	0.00
Mixed Use (Residential, Office & Cafe)	1878144.0	23063160.00	0.00
Commercial (Office)	0.0	0.00	0.00
Semi detached	0.0	1864.27	0.00
SMR	0.0	0.00	0.00
Single detached	0.0	1547.01	13.19
SNR	0.0	2504.95	0.00

Building Type	Sitework/1 \
Apartment building	23188.8
Educational building (University)	0.0
Institutional (Police Headquarters)	0.0
Laneway Suite	0.0
Mixed Use (Residential, Office & Cafe)	0.0
Commercial (Office)	0.0
Semi detached	0.0
SMR	0.0
Single detached	0.0
SNR	0.0

Building Type	Special Construction And Demolition/1 \
Apartment building	60316.8
Educational building (University)	0.0
Institutional (Police Headquarters)	0.0
Laneway Suite	0.0
Mixed Use (Residential, Office & Cafe)	62280.0
Commercial (Office)	0.0
Semi detached	0.0
SMR	0.0
Single detached	0.0
SNR	0.0

Building Type	Substructure/1	Substructure/2 \

Apartment building	20539176.00	0.00
Educational building (University)	0.00	0.00
Institutional (Police Headquarters)	0.00	0.00
Laneway Suite	58217.18	44.81
Mixed Use (Residential, Office & Cafe)	11822352.00	0.00
Commercial (Office)	0.00	0.00
Semi detached	97640.84	0.00
SMR	110089.90	8900.86
Single detached	180887.68	5347.87
SNR	93180.79	19334.28

Building Type	Substructure/4
Apartment building	0.00
Educational building (University)	0.00
Institutional (Police Headquarters)	0.00
Laneway Suite	1850.97
Mixed Use (Residential, Office & Cafe)	0.00
Commercial (Office)	0.00
Semi detached	0.00
SMR	0.00
Single detached	0.00
SNR	0.00

Next, we report the total amount of material falling under each uncertainty score by year of construction.

[34]:
```
f = lambda x: x.split('_')[-1].split('.')[0] #Select only the uncertainty score.
print('Average amount of material used per building, by year and uncertainty␣
 ↪score (%)')
result = pd.concat([df['Construction Date'],df[[c for c in df.columns if 'kg'␣
 ↪in c]].groupby(f,axis=1).sum()],axis=1).groupby('Construction Date').mean()
for k,v in result.iterrows():
    result.loc[k,:] = v/v.sum()
display(result.round(2))
```

```
Average amount of material used per building, by year and uncertainty score (%)
```

Construction Date	1	2	3	4
1913	0.85	0.08	0.00	0.07
1917	0.75	0.14	0.00	0.11
1969	0.50	0.37	0.00	0.13
1988	0.97	0.00	0.03	0.00
2007	0.97	0.00	0.03	0.00
2009	0.97	0.00	0.03	0.00
2011	0.94	0.03	0.03	0.00
2016	0.95	0.02	0.02	0.00

2017	0.97	0.00	0.03	0.00
2018	0.97	0.00	0.03	0.00
2019	0.96	0.04	0.00	0.00
2020	0.80	0.10	0.00	0.10
2021	0.78	0.09	0.00	0.13

5 4. Material Intensity

We can easily calculate material intensity by dividing takeoffs which are measured in kilograms by the `Gross Floor Area`:

[35]:
```
kilogram_columns = [d for d in df.columns if 'kg' in d]
df_mi = df[kilogram_columns].div(df['Gross Floor Area'],axis=0)
```

[36]:
```
kilogram_columns = [d for d in df.columns if 'kg' in d]
df_mi = df[kilogram_columns].div(df['Gross Floor Area'],axis=0)
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0:3]]
pd.concat([df[headings[1:]],df_mi[kilogram_columns].groupby(f,axis=1).
 ↪sum()],axis=1)[df['Building Type'] == 'SND']
```

[36]:

	Country	City	Quality / Stage of Data	Construction Date	Building Type	\
0	CA	TOR	00IFC	2021	SND	
1	CA	TOR	00IFC	2021	SND	
2	CA	TOR	00IFC	2021	SND	
3	CA	TOR	00IFC	2021	SND	
6	CA	TOR	00IFC	2021	SND	
7	CA	TOR	00IFC	2021	SND	
8	CA	TOR	00IFC	2021	SND	
9	CA	TOR	00IFC	2021	SND	
12	CA	TOR	00IFC	2021	SND	
13	CA	TOR	00IFC	2021	SND	
14	CA	TOR	00IFC	2021	SND	
15	CA	TOR	00IFC	2021	SND	
18	CA	TOR	00IFC	2021	SND	
19	CA	TOR	00IFC	2021	SND	
20	CA	TOR	00IFC	2020	SND	
21	CA	TOR	00IFC	2021	SND	
22	CA	TOR	00IFC	2021	SND	
24	CA	TOR	00IFC	2021	SND	
25	CA	TOR	00IFC	2021	SND	
27	CA	TOR	00IFC	2021	SND	
28	CA	TOR	00IFC	2021	SND	
30	CA	TOR	00IFC	2021	SND	
31	CA	TOR	00IFC	2021	SND	
32	CA	TOR	00IFC	2020	SND	
34	CA	TOR	00IFC	2021	SND	
35	CA	TOR	00IFC	2021	SND	

36	CA	TOR	00IFC	2021	SND
37	CA	TOR	00IFC	2020	SND
38	CA	TOR	00IFC	2021	SND
40	CA	TOR	00IFC	2021	SND
42	CA	TOR	00IFC	2021	SND
43	CA	TOR	00IFC	2021	SND
44	CA	TOR	00IFC	2021	SND
45	CA	TOR	00IFC	2021	SND
46	CA	TOR	00IFC	2021	SND
48	CA	TOR	00IFC	2020	SND
49	CA	TOR	00IFC	2021	SND

	Gross Floor Area	Conveying	Exterior Horizontal Enclosures	\
0	521.18	0.0	11.137992	
1	389.24	0.0	5.461939	
2	411.64	0.0	3.786074	
3	269.56	0.0	6.503479	
6	445.99	0.0	11.933511	
7	438.45	0.0	12.707195	
8	714.07	0.0	12.865930	
9	343.24	0.0	4.300619	
12	226.89	0.0	12.424245	
13	611.73	0.0	5.140200	
14	343.44	0.0	6.494467	
15	613.38	0.0	13.090524	
18	178.38	0.0	9.782438	
19	323.80	0.0	9.824569	
20	837.56	0.0	13.521848	
21	587.86	0.0	6.949783	
22	568.21	0.0	12.754287	
24	294.84	0.0	3.650542	
25	496.77	0.0	5.352985	
27	643.30	0.0	11.769043	
28	701.61	0.0	11.799093	
30	378.70	0.0	5.522739	
31	324.16	0.0	5.361174	
32	533.53	0.0	8.494907	
34	423.03	0.0	11.102019	
35	328.16	0.0	10.234937	
36	421.59	0.0	12.223172	
37	628.59	0.0	10.408758	
38	464.51	0.0	4.118745	
40	346.14	0.0	11.787081	
42	891.97	0.0	10.710312	
43	525.61	0.0	18.918490	
44	502.87	0.0	6.014586	
45	379.18	0.0	6.169302	

```
46            549.65        0.0                      11.310711
48            393.82        0.0                      16.116861
49            648.14        0.0                       9.684756

    Exterior Vertical Enclosures  Foundations  …  Interior Finishes  \
0                     136.939623   335.649367  …           8.309413
1                      69.018253   281.318698  …           6.490936
2                     101.450370   464.462195  …           4.574905
3                     188.215196   255.359136  …           8.510443
6                      61.325975   295.116668  …           6.391063
7                     130.552921   269.468463  …           6.584780
8                     104.310510   276.917123  …           6.563894
9                     210.632241   283.893850  …           8.940907
12                    186.668275   261.874926  …           6.134611
13                    102.332008   343.714248  …           7.638991
14                    147.104280   424.099610  …           7.860800
15                    156.986570   298.537712  …           8.068881
18                    112.523711   371.149916  …           9.551856
19                    186.570501   148.769711  …           9.483653
20                     91.689386   317.583491  …           7.152371
21                     94.557055   428.185321  …           6.754074
22                     83.789887   255.012975  …           7.860492
24                    127.856507   261.274626  …           4.807604
25                     89.883144   251.725837  …           5.921358
27                     83.949693   156.365248  …           8.492430
28                     53.418023   266.164355  …           7.952623
30                    164.214896   403.602589  …           7.221059
31                    190.512918   377.853541  …           6.597902
32                     68.518430   309.062696  …           6.648595
34                    154.072547   243.607664  …           4.717349
35                    184.202156   388.744353  …           5.648226
36                    158.716507   424.443503  …           5.625641
37                    136.076590   369.744859  …           5.699975
38                    151.068033   412.845205  …           7.621364
40                    146.479339   287.564257  …           7.916204
42                    213.677214   245.205806  …           7.577250
43                    109.529933   498.010299  …           7.954358
44                     91.481074   278.679758  …           4.564488
45                    172.418003   391.303861  …           6.339432
46                    127.866168   266.468237  …           6.701647
48                    140.069509   188.980245  …          10.629628
49                    131.118584   347.187490  …           5.089382

    Plumbing  Site Improvements  Slabs-On-Grade  Special Construction  \
0        0.0                0.0      273.972401                   0.0
1        0.0                0.0      192.874465                   0.0
2        0.0                0.0      170.733356                   0.0
```

3	0.0	0.0	124.186526	0.0
6	0.0	0.0	153.061618	0.0
7	0.0	0.0	211.910108	0.0
8	0.0	0.0	266.709576	0.0
9	0.0	0.0	138.510228	0.0
12	0.0	0.0	129.263543	0.0
13	0.0	0.0	165.513154	0.0
14	0.0	0.0	129.532248	0.0
15	0.0	0.0	166.414337	0.0
18	0.0	0.0	223.398638	0.0
19	0.0	0.0	158.178114	0.0
20	0.0	0.0	143.282268	0.0
21	0.0	0.0	237.918968	0.0
22	0.0	0.0	199.364347	0.0
24	0.0	0.0	131.174185	0.0
25	0.0	0.0	242.284758	0.0
27	0.0	0.0	152.407914	0.0
28	0.0	0.0	169.419640	0.0
30	0.0	0.0	179.868896	0.0
31	0.0	0.0	132.696247	0.0
32	0.0	0.0	135.390288	0.0
34	0.0	0.0	147.458950	0.0
35	0.0	0.0	128.887840	0.0
36	0.0	0.0	147.225241	0.0
37	0.0	0.0	186.334547	0.0
38	0.0	0.0	145.273403	0.0
40	0.0	0.0	139.821081	0.0
42	0.0	0.0	138.994603	0.0
43	0.0	0.0	139.646277	0.0
44	0.0	0.0	182.059329	0.0
45	0.0	0.0	158.446049	0.0
46	0.0	0.0	154.805714	0.0
48	0.0	0.0	198.860705	0.0
49	0.0	0.0	199.209464	0.0

	Subgrade Enclosures	Substructure Interior	\
0	9.652903	0.000000	
1	6.851955	0.000000	
2	11.298572	0.000000	
3	4.351465	0.000000	
6	9.478642	0.054452	
7	4.218921	0.000000	
8	8.902623	0.000000	
9	9.601245	0.000000	
12	3.818403	0.935612	
13	7.722754	0.000000	
14	9.135529	0.000000	

15	4.868508	0.467438
18	0.000000	0.000000
19	4.617006	0.000000
20	7.131170	0.000000
21	7.959752	0.000000
22	6.339651	0.000000
24	7.469048	0.000000
25	9.448689	0.078017
27	0.000000	0.096759
28	11.919460	0.000000
30	7.509119	0.330172
31	5.073992	0.000000
32	8.867868	0.000000
34	0.000000	0.000000
35	4.762839	0.000000
36	9.538939	0.000000
37	6.039206	1.461249
38	9.071017	0.000000
40	7.568785	0.394416
42	4.540919	0.371810
43	6.720435	0.000000
44	6.092739	0.000000
45	9.489156	0.195110
46	6.042229	0.499896
48	6.057127	1.647329
49	7.221222	1.208104

	Substructure Related Activities	Superstructure	Water And Gas Mitigation
0	0.0	30.228003	0.0
1	0.0	26.271523	0.0
2	0.0	23.756286	0.0
3	0.0	30.517748	0.0
6	0.0	39.906513	0.0
7	0.0	39.907474	0.0
8	0.0	38.291591	0.0
9	0.0	35.370538	0.0
12	0.0	35.355314	0.0
13	0.0	33.388004	0.0
14	0.0	39.370016	0.0
15	0.0	40.958564	0.0
18	0.0	63.006044	0.0
19	0.0	36.597047	0.0
20	0.0	28.734226	0.0
21	0.0	37.457583	0.0
22	0.0	36.265538	0.0
24	0.0	30.389475	0.0
25	0.0	43.728928	0.0

```
27                                0.0        35.393414                 0.0
28                                0.0        39.408113                 0.0
30                                0.0        82.392236                 0.0
31                                0.0        46.380703                 0.0
32                                0.0        25.469871                 0.0
34                                0.0        35.666107                 0.0
35                                0.0        49.404111                 0.0
36                                0.0        34.035382                 0.0
37                                0.0        47.065025                 0.0
38                                0.0        37.921434                 0.0
40                                0.0        27.740220                 0.0
42                                0.0        29.045531                 0.0
43                                0.0        33.265489                 0.0
44                                0.0        37.265275                 0.0
45                                0.0        46.860447                 0.0
46                                0.0        31.152827                 0.0
48                                0.0        49.899420                 0.0
49                                0.0        38.021046                 0.0

[37 rows x 21 columns]
```

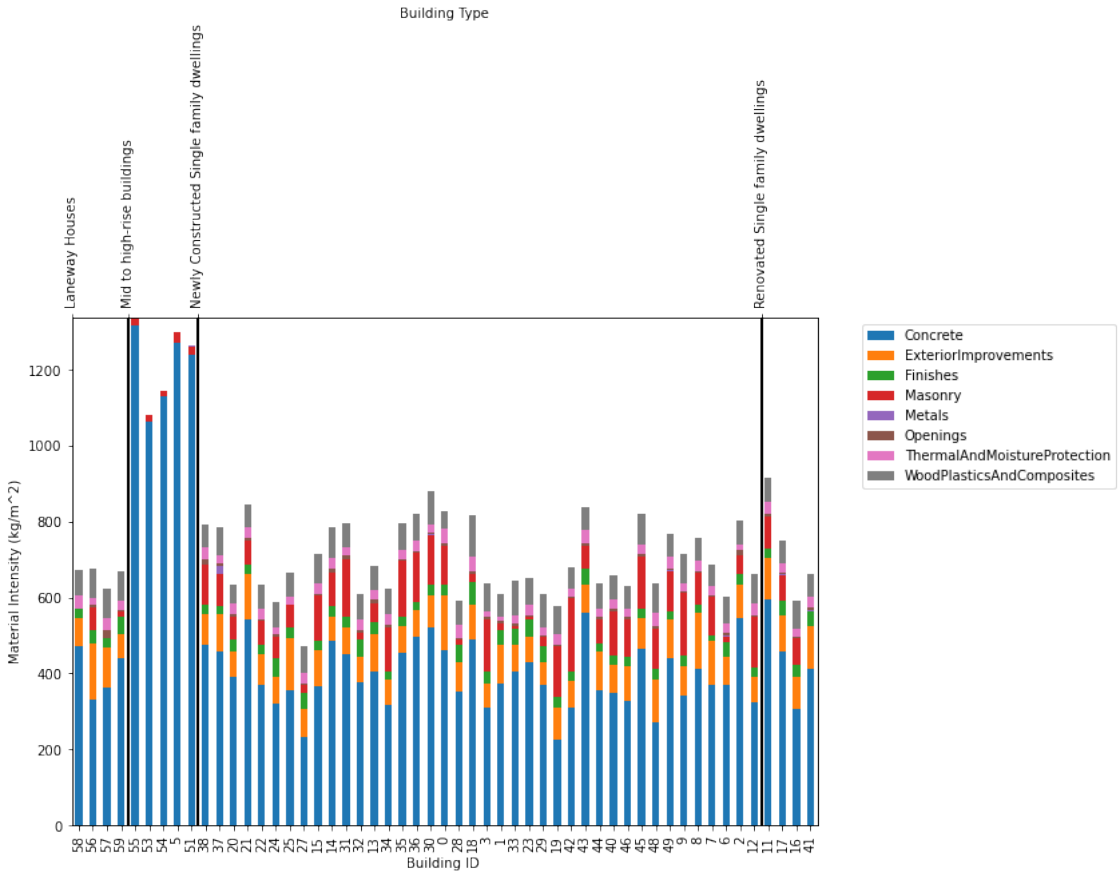
[37]:
```
master_format_convert = {v:k for k,v in {
    'Concrete':'03',
    'Masonry':'04',
    'Metals':'05',
    'WoodPlasticsAndComposites':'06',
    'ThermalAndMoistureProtection':'07',
    'Finishes':'09',
    'Openings':'08',
    'Earthwork':'31',
    'ExteriorImprovements':'32'
}.items() }
```

[38]:
```
f = lambda x: master_format_convert[re.split('[_\.\ ]',x)[4]]
toplot = pd.concat([df[headings[1:]],df_mi[kilogram_columns].groupby(f,axis=1).
 ↪sum()],axis=1).sort_values(['Building Type'])
```

[39]:
```
types_to_keep = ['APB','SND','SNR','SMR','SMD','ADU','SEC','ROW','LNW']
toplot = toplot[toplot['Building Type'].isin(types_to_keep)]
building_type_map = {
    'APB':'Mid to high-rise buildings',
    'SND':'Newly Constructed Single family dwellings',
    'SNR':'Renovated Single family dwellings',
    'SMD':'Newly Constructed Single family dwellings',
    'SMR':'Renovated Single family dwellings',
    'ADU':'Newly Constructed Single family dwellings',
    'SEC':'Newly Constructed Single family dwellings',
```

```
    'ROW':'Newly Constructed Single family dwellings',
    'LNW':'Laneway Houses'
}

toplot['Building Type'] = toplot['Building Type'].replace(building_type_map)
toplot = toplot.sort_values('Building Type')
```

[40]:
```
fig, ax = plt.subplots(figsize=(10,7))

cols = toplot.columns[6:]
margin_bottom = np.zeros(len(toplot))

cmap = plt.get_cmap('tab10')

for num, col in enumerate(cols):
    values = toplot[col].values

    toplot[col].plot.bar(x='Year',y='Value', ax=ax, stacked=True,
                                    bottom = margin_bottom, color=cmap(num),␣
 ↪label=col)
    margin_bottom += values
plt.legend(bbox_to_anchor=(1.05, 1), loc='upper left')
plt.ylabel('Material Intensity (kg/m^2)')
plt.xlabel('Building ID ')
ax2 = ax.twiny()
ax2.set_xlim(0, len(toplot))
ax2.set_xticks([k for k,v in enumerate(toplot['Building Type'].values) if v !=␣
 ↪toplot['Building Type'].values[k-1] or k==0])
for tick in ax2.get_xticklabels():
    tick.set_rotation(90)
ax2.set_xticklabels([v for k,v in enumerate(toplot['Building Type'].values) if␣
 ↪v != toplot['Building Type'].values[k-1] or k==0])
ax2.set_xlabel("Building Type")
plt.grid(color='black',linewidth=2)

plt.show()
```



[41]:
```
print('Mean Material Intensity:')
display(toplot.groupby('Building Type').mean().iloc[:,1:].round(2))
print('Std Dev Material Intensity:')
display(toplot.groupby('Building Type').std().iloc[:,1:].round(2))
```

```
Mean Material Intensity:
```

Building Type	Gross Floor Area	Concrete
Laneway Houses	150.01	402.07
Mid to high-rise buildings	45505.41	1204.29
Newly Constructed Single family dwellings	461.18	396.71
Renovated Single family dwellings	277.06	442.97

Building Type	ExteriorImprovements	Finishes
Laneway Houses	97.09	32.40
Mid to high-rise buildings	0.00	0.00
Newly Constructed Single family dwellings	86.16	31.17
Renovated Single family dwellings	100.30	33.64

Building Type	Masonry	Metals	Openings	\
Laneway Houses	17.83	0.13	9.62	
Mid to high-rise buildings	19.81	0.69	0.00	
Newly Constructed Single family dwellings	83.77	0.96	5.99	
Renovated Single family dwellings	55.31	0.74	5.84	

Building Type	ThermalAndMoistureProtection	\
Laneway Houses	25.88	
Mid to high-rise buildings	0.00	
Newly Constructed Single family dwellings	25.63	
Renovated Single family dwellings	26.98	

Building Type	WoodPlasticsAndComposites
Laneway Houses	74.98
Mid to high-rise buildings	0.00
Newly Constructed Single family dwellings	68.82
Renovated Single family dwellings	64.59

Std Dev Material Intensity:

Building Type	Gross Floor Area	Concrete	\
Laneway Houses	62.86	65.17	
Mid to high-rise buildings	21930.72	103.88	
Newly Constructed Single family dwellings	168.17	82.14	
Renovated Single family dwellings	117.28	120.26	

Building Type	ExteriorImprovements	Finishes	\
Laneway Houses	37.25	10.08	
Mid to high-rise buildings	0.00	0.00	
Newly Constructed Single family dwellings	22.30	9.40	
Renovated Single family dwellings	12.94	6.38	

Building Type	Masonry	Metals	Openings	\
Laneway Houses	27.54	0.26	9.08	
Mid to high-rise buildings	5.50	0.58	0.00	
Newly Constructed Single family dwellings	49.26	3.35	2.21	
Renovated Single family dwellings	37.88	0.86	1.43	

Building Type	ThermalAndMoistureProtection	\
Laneway Houses	7.72	
Mid to high-rise buildings	0.00	

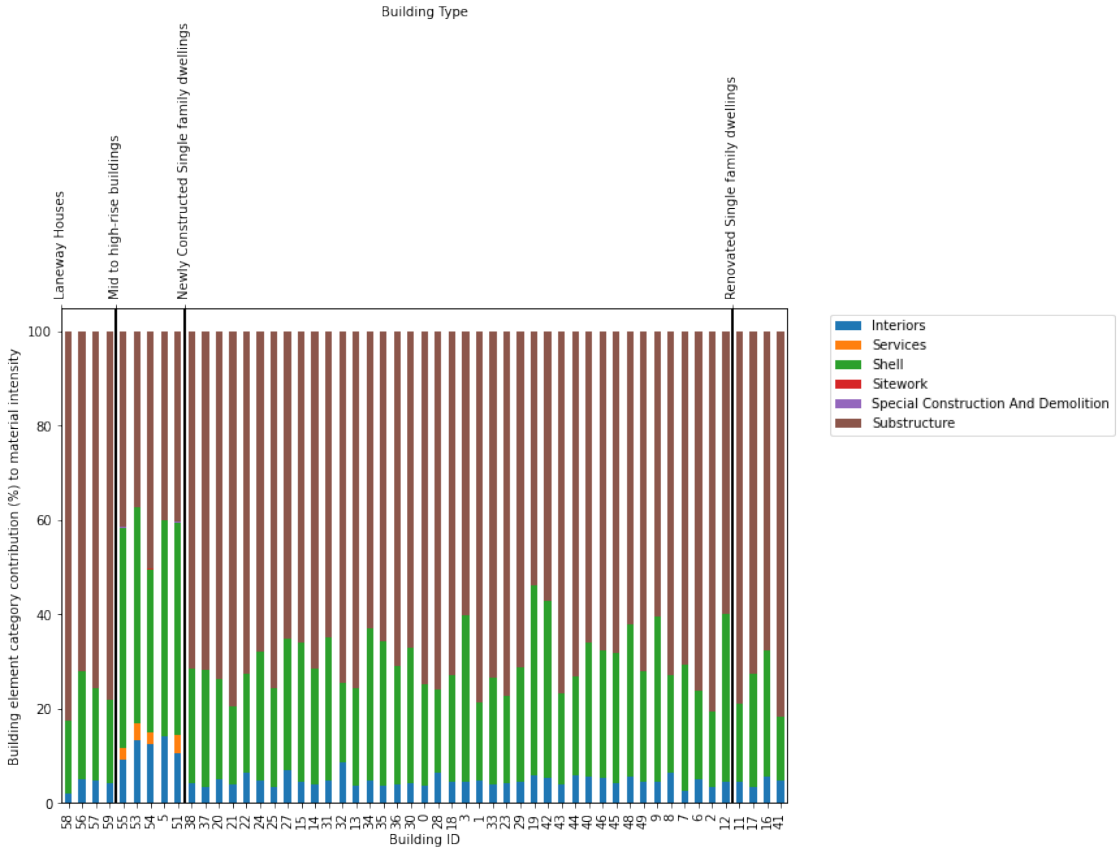
```
Newly Constructed Single family dwellings                          6.14
Renovated Single family dwellings                                  5.44
```

```
                                                WoodPlasticsAndComposites
Building Type
Laneway Houses                                                       5.41
Mid to high-rise buildings                                           0.00
Newly Constructed Single family dwellings                           11.58
Renovated Single family dwellings                                    6.55
```

[42]:
```
df_mi = df[kilogram_columns].div(df['Gross Floor Area'],axis=0)
```

[43]:
```
df_mi = df[kilogram_columns].div(df['Gross Floor Area'],axis=0)
df_mi = df_mi.div(df_mi.sum(axis=1),axis=0) * 100
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0]]
toplot = pd.concat([df[headings[1:]],df_mi[kilogram_columns].groupby(f,axis=1).
 ↪sum()],axis=1).sort_values('Building Type')
toplot = toplot[toplot['Building Type'].isin(types_to_keep)]
toplot['Building Type'] = toplot['Building Type'].replace(building_type_map)
toplot = toplot.sort_values('Building Type')
fig, ax = plt.subplots(figsize=(10,7))

cols = toplot.columns[6:]
margin_bottom = np.zeros(len(toplot))

cmap = plt.get_cmap('tab10')

for num, col in enumerate(cols):
    values = toplot[col].values

    toplot[col].plot.bar(x='Year',y='Value', ax=ax, stacked=True,
                                    bottom = margin_bottom, color=cmap(num),␣
 ↪label=col)
    margin_bottom += values
plt.legend(bbox_to_anchor=(1.05, 1), loc='upper left')
plt.xlabel('Building ID')
plt.ylabel('Building element category contribution (%) to material intensity')

ax2 = ax.twiny()
ax2.set_xlim(0, len(toplot))
ax2.set_xticks([k for k,v in enumerate(toplot['Building Type'].values) if v !=␣
 ↪toplot['Building Type'].values[k-1] or k==0])
for tick in ax2.get_xticklabels():
    tick.set_rotation(90)
ax2.set_xticklabels([v for k,v in enumerate(toplot['Building Type'].values) if␣
 ↪v != toplot['Building Type'].values[k-1] or k==0])
ax2.set_xlabel("Building Type")
```

```
plt.grid(color='black',linewidth=2)
plt.show()
```



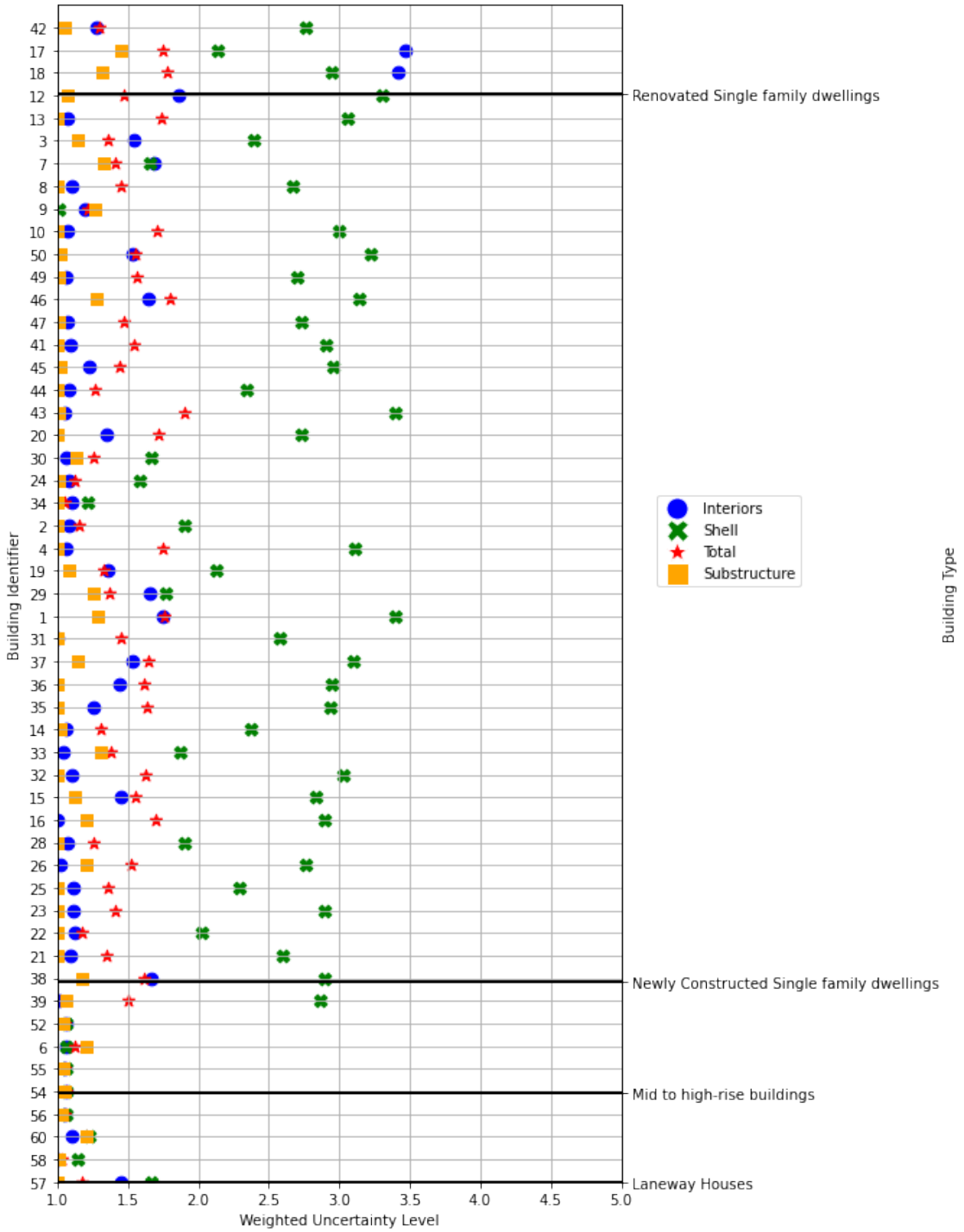
[44]:
```
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0]] + '/' + re.split('[_\.\␣
 ↪]',x)[-1]
toplot = df_mi[kilogram_columns].groupby(f,axis=1).sum()
```

[45]:
```
df_mi = df[kilogram_columns].div(df['Gross Floor Area'],axis=0)
df_mi = df_mi.div(df_mi.sum(axis=1),axis=0)
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0]] + '/' + re.split('[_\.\␣
 ↪]',x)[-1]
toplot = df_mi[kilogram_columns].groupby(f,axis=1).sum()
for i in range(1,5):
    toplot[f'Total/{i}'] = 0
for k,v in toplot.iteritems():
    toplot[f'Total/{k.split("/")[1]}'] += v
toplot_out = deepcopy(toplot)
for k,v in toplot.iteritems():
    toplot_out[k] = (v/toplot[[c for c in toplot.columns if k.split('/')[0] in␣
 ↪c]].sum(axis=1)) * int(k.split('/')[1])
```

```
f = lambda x: x.split('/')[0]
toplot_out = pd.concat([df['Building Type'],toplot_out.groupby(f,axis=1).
 ↪sum()],axis=1).sort_values('Building Type')
toplot_out = toplot_out.reset_index()
toplot_out['index'] += 1
toplot_out['index'] = toplot_out['index'].astype('str')
```

[46]:
```
toplot_out = toplot_out[toplot_out['Building Type'].isin(types_to_keep)]
toplot_out['Building Type'] = toplot_out['Building Type'].
 ↪replace(building_type_map)
toplot_out = toplot_out.sort_values('Building Type')
```

[47]:
```
from matplotlib.lines import Line2D
fig, ax = plt.subplots(figsize=(7,15))
ax.set_xlim(1,5)
ax.set_ylim(1,len(toplot_out))
# ax.set_yticks(toplot_out['index'])
handles = []
for v,m,c in␣
 ↪[('Interiors','o','blue'),('Shell','X','green'),('Total','*','red'),('Substructure','s','or
 ↪
    ax.scatter(x=toplot_out[v].values,y=toplot_out['index'].values, marker=m,␣
 ↪color=c, s=75)
    handles.append(
        Line2D([0], [0], marker=m, color='w', label=v,
                               markerfacecolor=c, markersize=15)
    )
plt.legend(handles=handles,bbox_to_anchor=(1.05, 0.5), loc='lower left')
plt.ylabel('Building Identifier')
plt.xlabel('Weighted Uncertainty Level')
plt.grid()
ax2 = ax.twinx()
ax2.set_ylim(0, len(toplot_out))
ax2.set_yticks([k for k,v in enumerate(toplot_out['Building Type'].values) if v␣
 ↪!= toplot_out['Building Type'].values[k-1] or k==0])
# for tick in ax2.get_yticklabels():
#     tick.set_rotation(90)
ax2.set_yticklabels([v for k,v in enumerate(toplot_out['Building Type'].values)␣
 ↪if v != toplot_out['Building Type'].values[k-1] or k==0])
ax2.set_ylabel("Building Type")


plt.grid(color='black',linewidth=2)
```


Building Identifier
Weighted Uncertainty Level
Building Type
Interiors
Shell
Total
Substructure
Renovated Single family dwellings
Newly Constructed Single family dwellings
Mid to high-rise buildings
Laneway Houses

[ ]:

[ ]: