Sample

May 12, 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   
```

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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  …  2_B2010.80.000_07 26 13.00_kg_2.1  \
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  …                               3.93
```

```
    2_B2010.80.000_07 27 00.00_kg_2.1  2_B2010.80.000_07 21 13.00_kg_2.1  \
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   
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22                                NaN                                NaN   
23                                NaN                                NaN   
24                                NaN                                NaN   
25                                NaN                                NaN   
26                                NaN                                NaN   
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40                                NaN                                NaN   
41                                NaN                                NaN   
42                                NaN                                NaN   
43                                NaN                                NaN   
44                                NaN                                NaN   
45                                NaN                                NaN   
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46                                NaN                                NaN
47                                NaN                                NaN
48                                NaN                                NaN
49                                NaN                                NaN
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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

    2_B2010.10.000_09 24 23.00_kg_2.1  0B1_A5020.10.000_06 11 00.00_kg_2.1  \
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
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12                                NaN                                  NaN
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26                                NaN                                  NaN
27                                NaN                                  NaN
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29                                NaN                                  NaN
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31                                NaN                                  NaN
32                                NaN                                  NaN
33                                NaN                                  NaN
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43                                NaN                                  NaN
44                                NaN                                  NaN
45                                NaN                                  NaN
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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_1.1  0B1_A5020.10.000_09 21 16.00_kg_1.1  \
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
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16                                  NaN                                  NaN
17                                  NaN                                  NaN
18                                  NaN                                  NaN
19                                  NaN                                  NaN
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21                                  NaN                                  NaN
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26                                  NaN                                  NaN
27                                  NaN                                  NaN
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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_1.1  00R_B3010.90.000_07 21 13.00_kg_1.1  \
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

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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_1.1
0                                   NaN
1                                   NaN
2                                   NaN
3                                   NaN
4                                   NaN
5                                   NaN
6                                   NaN
7                                   NaN
8                                   NaN
9                                   NaN
10                                  NaN
11                                  NaN
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31                                  NaN
32                                  NaN
```

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33                                  NaN
34                                  NaN
35                                  NaN
36                                  NaN
37                                  NaN
38                                  NaN
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43                                  NaN
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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 4369 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

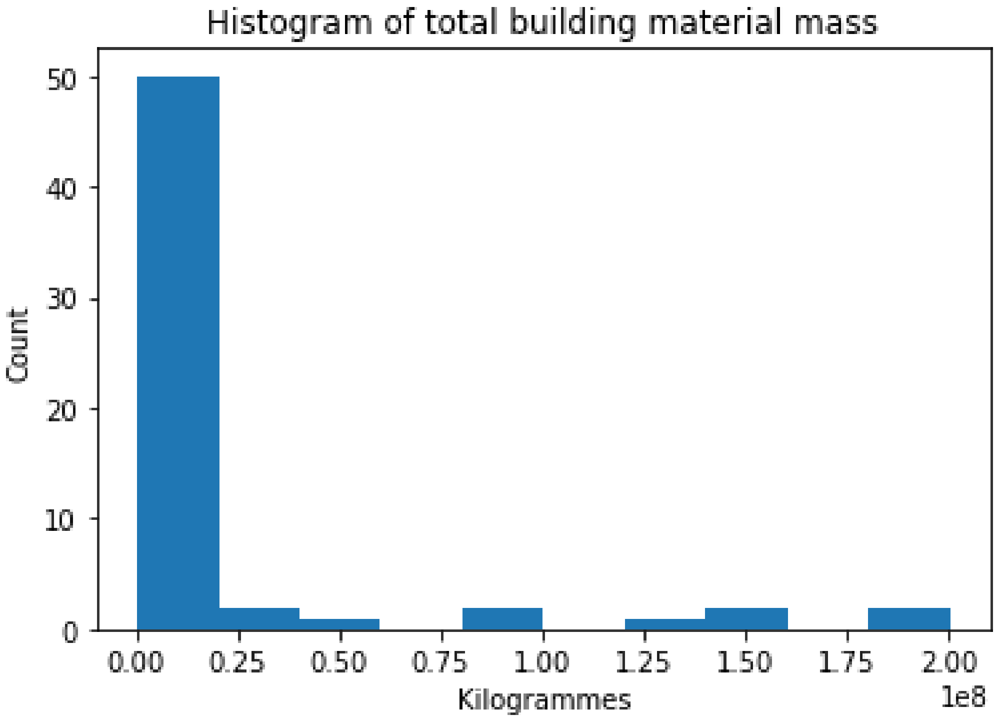
Here we plot building material mass.

[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  3.418472e+05
1                2021           SND            389.24  2.165723e+05
2                2021           SND            411.64  3.818598e+05
3                2021           SND            269.56  1.347385e+05
4                2011           OFF          11248.00  0.000000e+00
5                2011           APB          11317.00  0.000000e+00
6                2021           SND            445.99  2.590405e+05
7                2021           SND            438.45  2.348862e+05
8                2021           SND            714.07  3.855360e+05
9                2021           SND            343.24  1.912945e+05
10               2009           OFF          73083.00  0.000000e+00
11               1917           SMR            199.93  1.985463e+05
12               2021           SND            226.89  1.167094e+05
13               2021           SND            611.73  4.122563e+05
14               2021           SND            343.44  2.873628e+05
15               2021           SND            613.38  3.579554e+05
16               1969           SNR            413.72  1.858717e+05
17               1969           SNR            333.49  2.372760e+05
18               2021           SND            178.38  1.281646e+05
19               2021           SND            323.80  9.466877e+04
20               2020           SND            837.56  5.211311e+05
21               2021           SND            587.86  4.910742e+05
22               2021           SND            568.21  2.830367e+05
23               2021           SMD            234.73  1.712043e+05
24               2021           SND            294.84  1.516173e+05
25               2021           SND            496.77  2.410672e+05
26               2007           OFF          73600.00  0.000000e+00
27               2021           SND            643.30  1.943771e+05
28               2021           SND            701.61  3.621866e+05
29               2021           SMD            257.75  1.636661e+05
30               2021           SND            378.70  2.954456e+05
31               2021           SND            324.16  2.377269e+05
32               2020           SND            533.53  3.254092e+05
33               2020           SMD            254.05  1.776420e+05
34               2021           SND            423.03  1.996054e+05
35               2021           SND            328.16  2.477087e+05
36               2021           SND            421.59  3.520846e+05
37               2020           SND            628.59  4.597656e+05
38               2021           SND            464.51  3.772762e+05
39               2017           EDU           8983.00  0.000000e+00
40               2021           SND            346.14  1.949726e+05
```

```
41               1913           SNR            161.08  1.072460e+05
42               2021           SND            891.97  4.315217e+05
43               2021           SND            525.61  5.135450e+05
44               2021           SND            502.87  2.744804e+05
45               2021           SND            379.18  2.874772e+05
46               2021           SND            549.65  2.871788e+05
47               2016           EDU           6819.00  0.000000e+00
48               2020           SND            393.82  1.458941e+05
49               2021           SND            648.14  4.432662e+05
50               1988           INS          21934.00  0.000000e+00
51               2018           APB          53146.02  2.231645e+07
52               2018           MIX          33975.25  8.440080e+06
53               2017           APB          69784.00  1.582589e+07
54               2017           APB          39409.04  1.870147e+07
55               2016           APB          53871.00  3.255024e+06
56               2020           LNW            137.23  6.222788e+04
57               2020           LNW            144.92  6.482345e+04
58               2019           LNW             83.10  6.695447e+04
59               2021           LNW            234.79  1.680143e+05

    Subgrade Enclosures  Slabs-On-Grade  Substructure Interior  \
0                   0.0    1.344244e+05                    0.0   
1                   0.0    7.152085e+04                    0.0   
2                   0.0    6.492922e+04                    0.0   
3                   0.0    3.190422e+04                    0.0   
4                   0.0    0.000000e+00                    0.0   
5                   0.0    0.000000e+00                    0.0   
6                   0.0    7.043836e+04                    0.0   
7                   0.0    8.578114e+04                    0.0   
8                   0.0    1.689375e+05                22614.4   
9                   0.0    4.066228e+04                    0.0   
10                  0.0    0.000000e+00                    0.0   
11                  0.0    3.943520e+04                    0.0   
12                  0.0    2.871974e+04                    0.0   
13                  0.0    8.280078e+04                    0.0   
14                  0.0    4.493672e+04                    0.0   
15                  0.0    8.438890e+04                    0.0   
16                  0.0    6.753628e+04                    0.0   
17                  0.0    5.244732e+04                    0.0   
18                  0.0    4.687724e+04                    0.0   
19                  0.0    4.736970e+04                    0.0   
20                  0.0    1.268970e+05                    0.0   
21                  0.0    1.373142e+05                    0.0   
22                  0.0    1.336938e+05                    0.0   
23                  0.0    2.588720e+04                    0.0   
24                  0.0    3.583642e+04                    0.0   
25                  0.0    1.027599e+05                    0.0   
```

```
26                  0.0    0.000000e+00                    0.0
27                  0.0    1.046046e+05                    0.0
28                  0.0    1.246644e+05                    0.0
29                  0.0    2.423771e+04                    0.0
30                  0.0    7.029444e+04                    0.0
31                  0.0    4.023936e+04                    0.0
32                  0.0    7.349277e+04                    0.0
33                  0.0    2.320773e+04                    0.0
34                  0.0    6.658572e+04                    0.0
35                  0.0    3.862318e+04                    0.0
36                  0.0    6.608874e+04                    0.0
37                  0.0    1.105763e+05                    0.0
38                  0.0    5.733554e+04                    0.0
39                  0.0    0.000000e+00                    0.0
40                  0.0    4.474196e+04                    0.0
41                  0.0    2.471316e+04                    0.0
42                  0.0    1.189866e+05                    0.0
43                  0.0    6.757370e+04                    0.0
44                  0.0    7.902094e+04                    0.0
45                  0.0    5.827598e+04                    0.0
46                  0.0    7.012780e+04                    0.0
47                  0.0    0.000000e+00                    0.0
48                  0.0    6.728550e+04                    0.0
49                  0.0    1.219806e+05                    0.0
50                  0.0    0.000000e+00                    0.0
51            5456016.0    7.295040e+05             22066896.0
52            3411360.0    7.669440e+05             10800576.0
53            6492336.0    2.814000e+06             28104000.0
54            7135440.0    1.809168e+06             15214560.0
55            6876336.0    1.434960e+06             45814368.0
56                  0.0    2.879696e+04                    0.0
57                  0.0    4.000507e+04                    0.0
58                  0.0    1.082552e+04                    0.0
59                  0.0    3.925598e+04                    0.0

    Substructure Related Activities  Superstructure  \
0                               0.0    3.877620e+03   
1                               0.0    2.795220e+03   
2                               0.0    3.057420e+02   
3                               0.0    2.424180e+01   
4                               0.0    0.000000e+00   
5                               0.0    0.000000e+00   
6                               0.0    1.066518e+03   
7                               0.0    3.941580e+03   
8                               0.0    8.099340e+03   
9                               0.0    1.888034e+03   
10                              0.0    0.000000e+00   
```

```
11                                 0.0    0.000000e+00
12                                 0.0    1.957166e+03
13                                 0.0    1.076300e+03
14                                 0.0    0.000000e+00
15                                 0.0    0.000000e+00
16                                 0.0    0.000000e+00
17                                 0.0    1.502968e+04
18                                 0.0    0.000000e+00
19                                 0.0    4.223600e+03
20                                 0.0    6.541620e+03
21                                 0.0    5.067160e+03
22                                 0.0    1.203268e+03
23                                 0.0    3.655220e+03
24                                 0.0    1.195496e+03
25                                 0.0    5.081800e+03
26                                 0.0    0.000000e+00
27                                 0.0    1.437894e+03
28                                 0.0    4.552840e+02
29                                 0.0    3.175800e+03
30                                 0.0    2.193020e+04
31                                 0.0    1.106080e+04
32                                 0.0    2.721960e+03
33                                 0.0    4.354580e+03
34                                 0.0    1.304862e+03
35                                 0.0    7.888300e+03
36                                 0.0    8.802460e+02
37                                 0.0    1.703748e+03
38                                 0.0    5.186320e+03
39                                 0.0    0.000000e+00
40                                 0.0    4.721620e+02
41                                 0.0    0.000000e+00
42                                 0.0    1.719932e+03
43                                 0.0    2.077620e+03
44                                 0.0    9.763680e+02
45                                 0.0    2.535020e+03
46                                 0.0    2.309780e+03
47                                 0.0    0.000000e+00
48                                 0.0    3.670240e+02
49                                 0.0    2.082640e+03
50                                 0.0    0.000000e+00
51                            266928.0    5.560013e+07
52                            225744.0    4.453070e+07
53                            339792.0    6.409243e+07
54                            552528.0    2.967154e+07
55                            186096.0    6.478267e+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                     1455792.0                        1075968.0
52                      810816.0                         784800.0
53                      656064.0                        1599744.0
54                      238176.0                              0.0
55                      318672.0                              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                     0.0        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
```

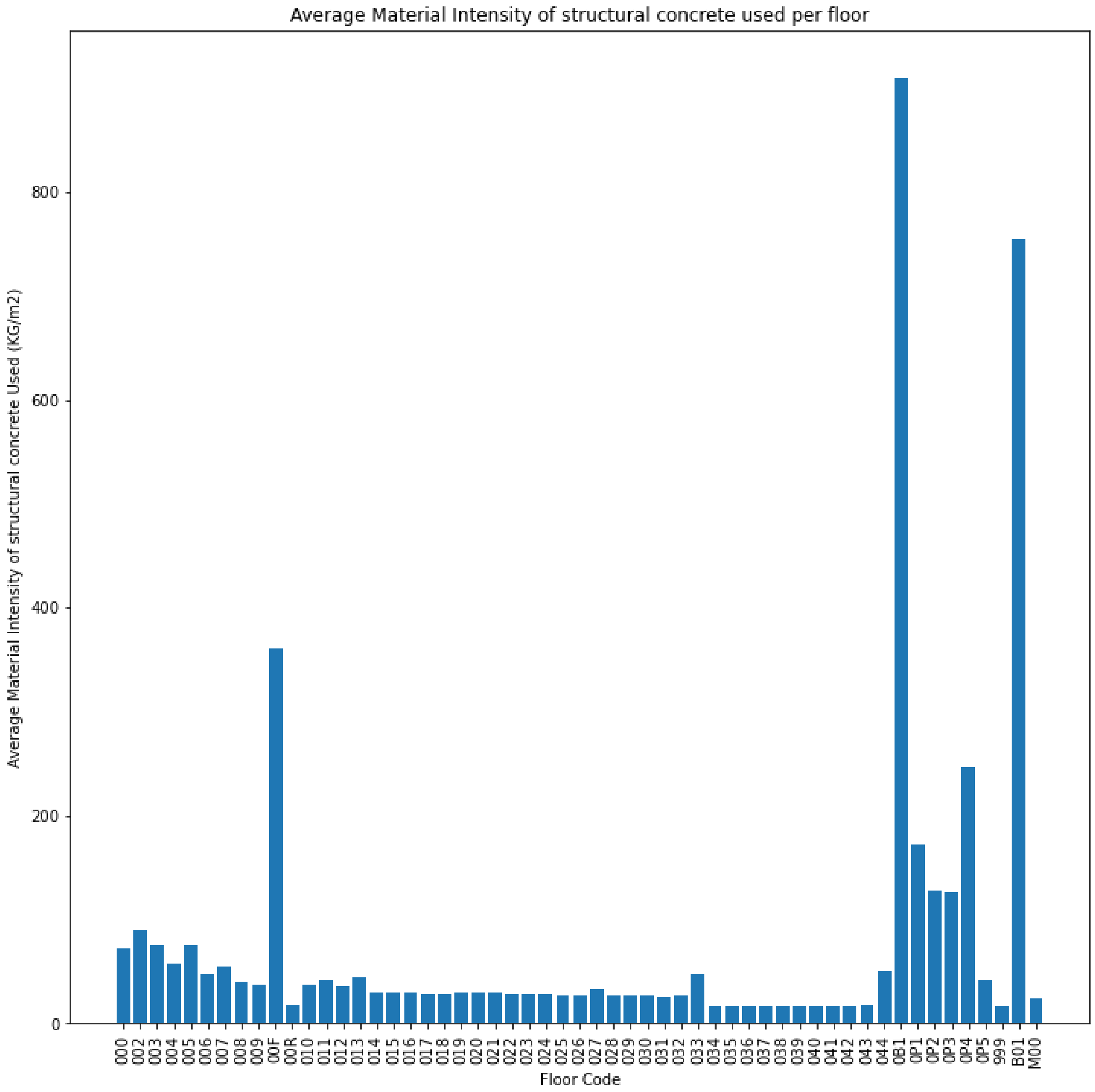
```
28                     0.0        0.0       0.0                   0.0
29                     0.0        0.0       0.0                   0.0
30                     0.0        0.0       0.0                   0.0
31                     0.0        0.0       0.0                   0.0
32                     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              13633392.0  4989120.0       0.0              161184.0
52              11786352.0  3658656.0   97632.0              124560.0
53              18101184.0  4608960.0  344064.0                   0.0
54              10361952.0  1723776.0  260304.0                   0.0
55              11209920.0  3328896.0       0.0              441984.0
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            36768.0
54           195120.0
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.

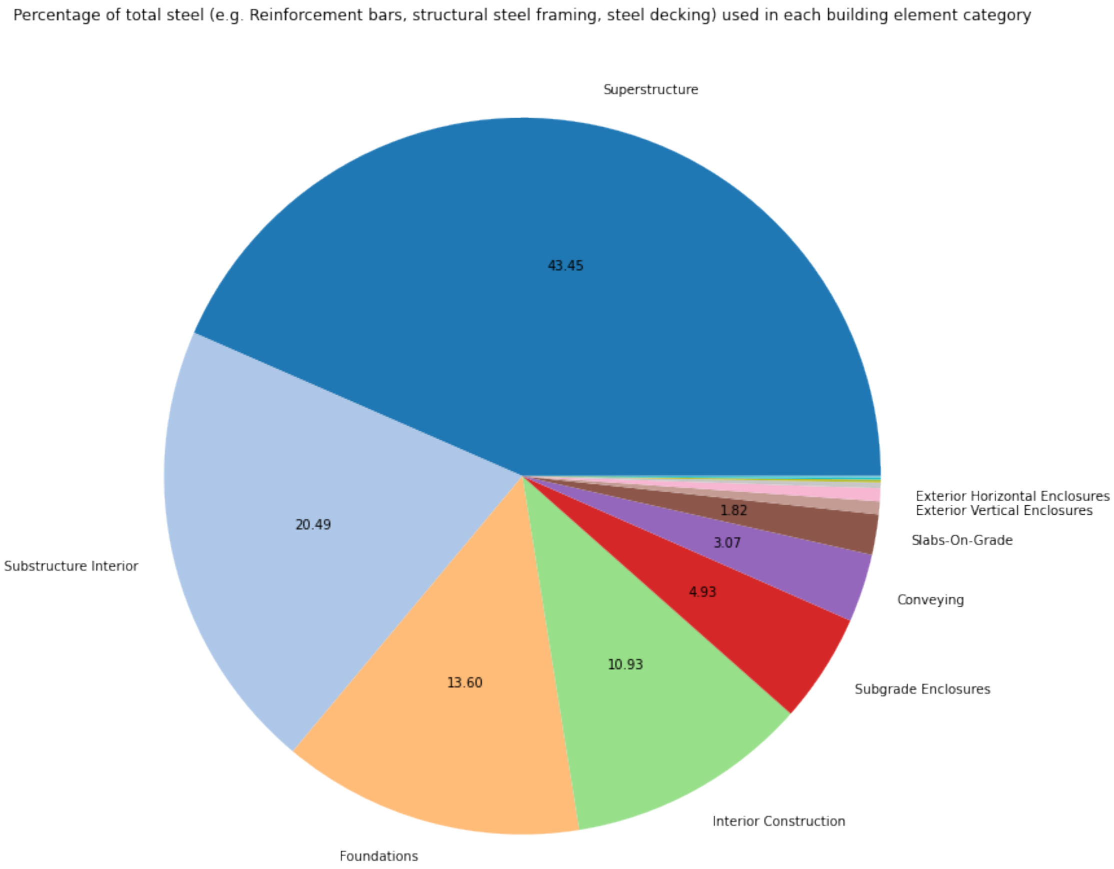
```
[14]: f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0:3]] #This function takes in a␣
       ↪full column name and returns only the Level 3 MasterFormat code.
      concrete_df = df[cols].groupby(f,axis=1).sum()
```

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

```
[15]: Superstructure                         4.313652e+06
      Substructure Interior                  2.033717e+06
      Foundations                            1.350052e+06
      Interior Construction                  1.084880e+06
      Subgrade Enclosures                    4.895248e+05
      Conveying                              3.051568e+05
      Slabs-On-Grade                         1.808602e+05
      Exterior Vertical Enclosures           5.799200e+04
      Exterior Horizontal Enclosures         5.767520e+04
      Substructure Related Activities        2.618480e+04
      Special Construction                   1.212880e+04
      Plumbing                               1.170000e+04
      Site Improvements                      3.864800e+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();
```


Percentage of total steel (e.g. Reinforcement bars, structural steel framing, steel decking) used in each building element category

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();

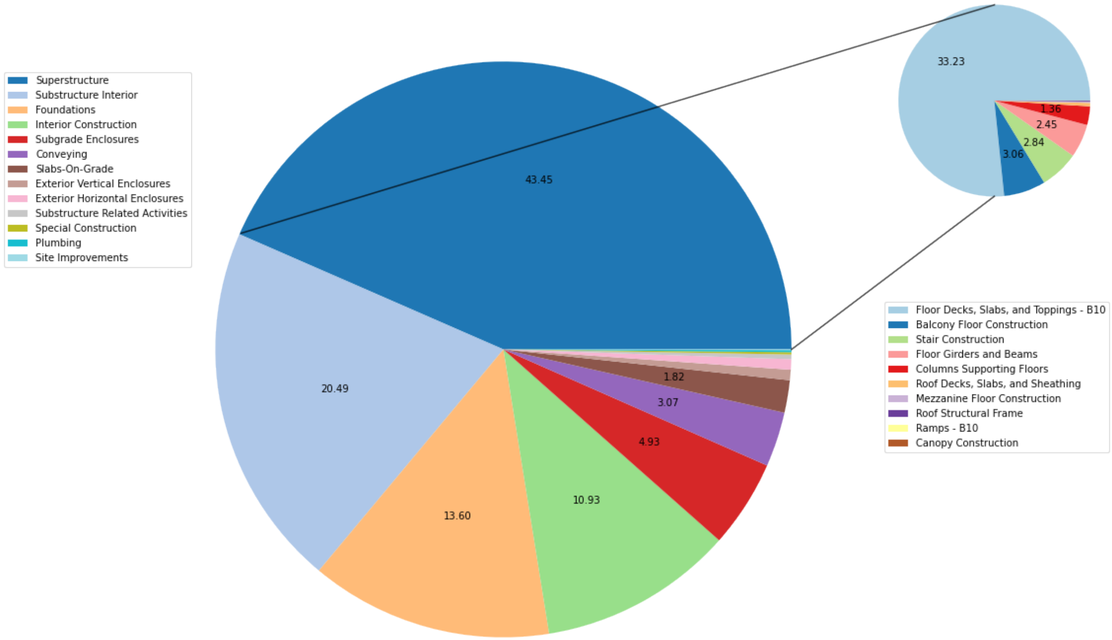
transFigure = fig.transFigure.inverted()

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
```

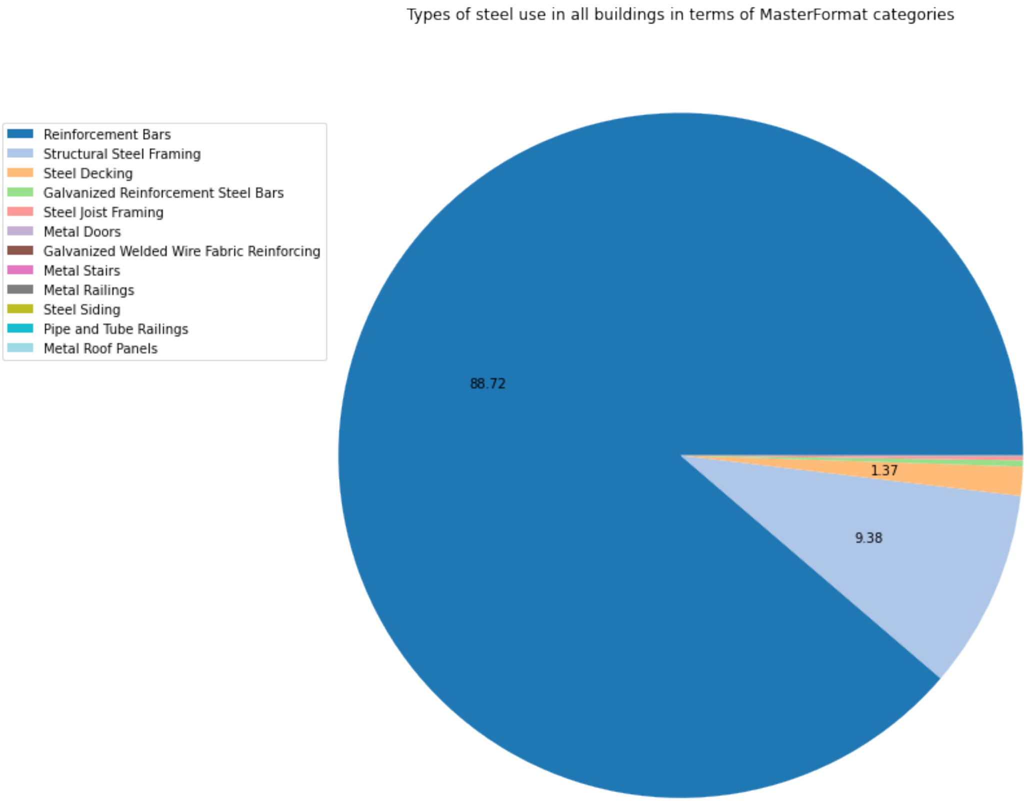
```
52    3
53    3
56    3
46    3
39    3
29    3
37    3
28    3
27    3
26    3
25    3
13    3
10    3
2     3
38    3
5     3
6     3
8     3
57    4
4     4
49    4
50    4
48    4
47    4
19    4
51    4
59    4
dtype: int64
```

[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')
```

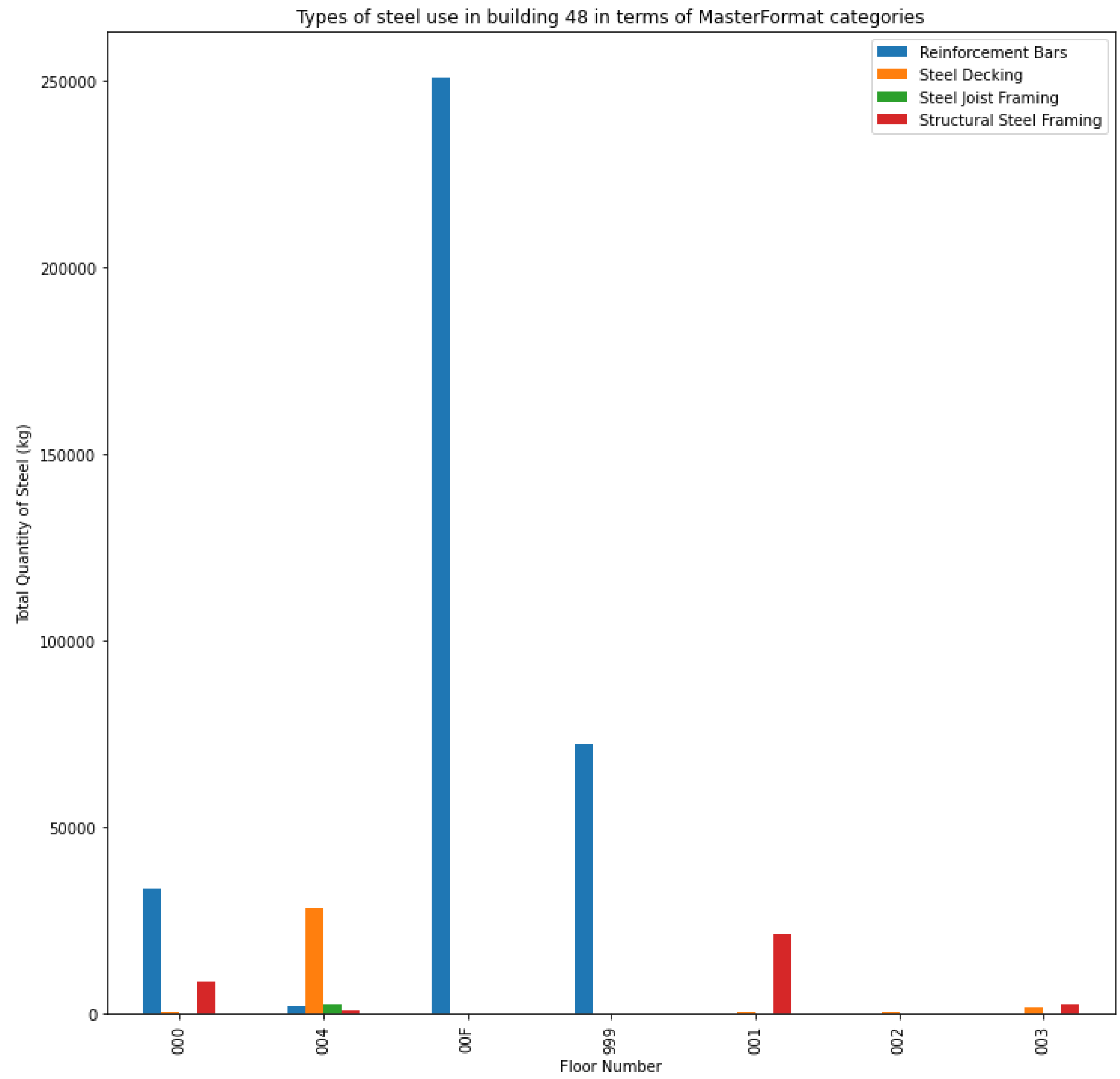


[24]:

```
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]:                    Gross Floor Area  Structural Concrete/000  \
      Construction Date
      1913                         161.080000             3.888760e+03
      1917                         199.930000             9.944600e+03
      1969                         373.605000             1.452444e+04
      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             7.191312e+06
2017                   39392.013333             8.168704e+06
2018                   43560.635000             1.178736e+07
2019                      83.100000             0.000000e+00
2020                     418.528571             1.967624e+04
2021                     445.404444             2.288333e+04

                   Structural Concrete/002  Structural Concrete/003  \
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                             5361024.0                3372456.0
2017                             1978560.0                2464672.0
2018                             3023784.0                2695872.0
2019                                   0.0                      0.0
2020                                   0.0                      0.0
2021                                   0.0                      0.0

                   Structural Concrete/004  Structural Concrete/005  \
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                             2114064.0                2113560.0
2017                             1556960.0                1366992.0
2018                             2646264.0                4329624.0
2019                                   0.0                      0.0
2020                                   0.0                      0.0
2021                                   0.0                      0.0

                   Structural Concrete/006  Structural Concrete/007  \
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                             2259360.0                3619704.0
2017                             1358752.0                1265040.0
2018                             1938120.0                1504416.0
2019                                   0.0                      0.0
2020                                   0.0                      0.0
2021                                   0.0                      0.0

                   Structural Concrete/008  Structural Concrete/009  …  \
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                             1715952.0                1715688.0  …
2017                             1302160.0                 851088.0  …
2018                             1469376.0                1469376.0  …
2019                                   0.0                      0.0  …
2020                                   0.0                      0.0  …
2021                                   0.0                      0.0  …

                   Structural Concrete/044  Structural Concrete/0B1  \
Construction Date
1913                                   0.0                 0.000000
1917                                   0.0                 0.000000
1969                                   0.0                 0.000000
1988                                   0.0                 0.000000
2007                                   0.0                 0.000000
2009                                   0.0                 0.000000
2011                                   0.0                 0.000000
2016                                   0.0                 0.000000
2017                             1156064.0                 0.000000
2018                                   0.0                 0.000000
2019                                   0.0             77779.984332
2020                                   0.0                 0.000000
2021                                   0.0              5757.507222

                   Structural Concrete/0P1  Structural Concrete/0P2  \
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                             4413336.0                3430056.0
2017                             6719360.0                4959520.0
2018                             7421040.0                5274120.0
2019                                   0.0                      0.0
2020                                   0.0                      0.0
2021                                   0.0                      0.0

                   Structural Concrete/0P3  Structural Concrete/0P4  \
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                             3192888.0               18263952.0
2017                             4881280.0                3730944.0
2018                             5513832.0                8186568.0
2019                                   0.0                      0.0
2020                                   0.0                      0.0
2021                                   0.0                      0.0

                   Structural Concrete/0P5  Structural Concrete/999  \
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                                   0.0                 310152.0
2017                              979872.0                 324016.0
2018                                   0.0                1123824.0
2019                                   0.0                      0.0
2020                                   0.0                      0.0
2021                                   0.0                      0.0

                   Structural Concrete/B01  Structural Concrete/M00
Construction Date
1913                         128070.380000                      0.0
1917                         228036.920000                      0.0
1969                         264556.030000                      0.0
```

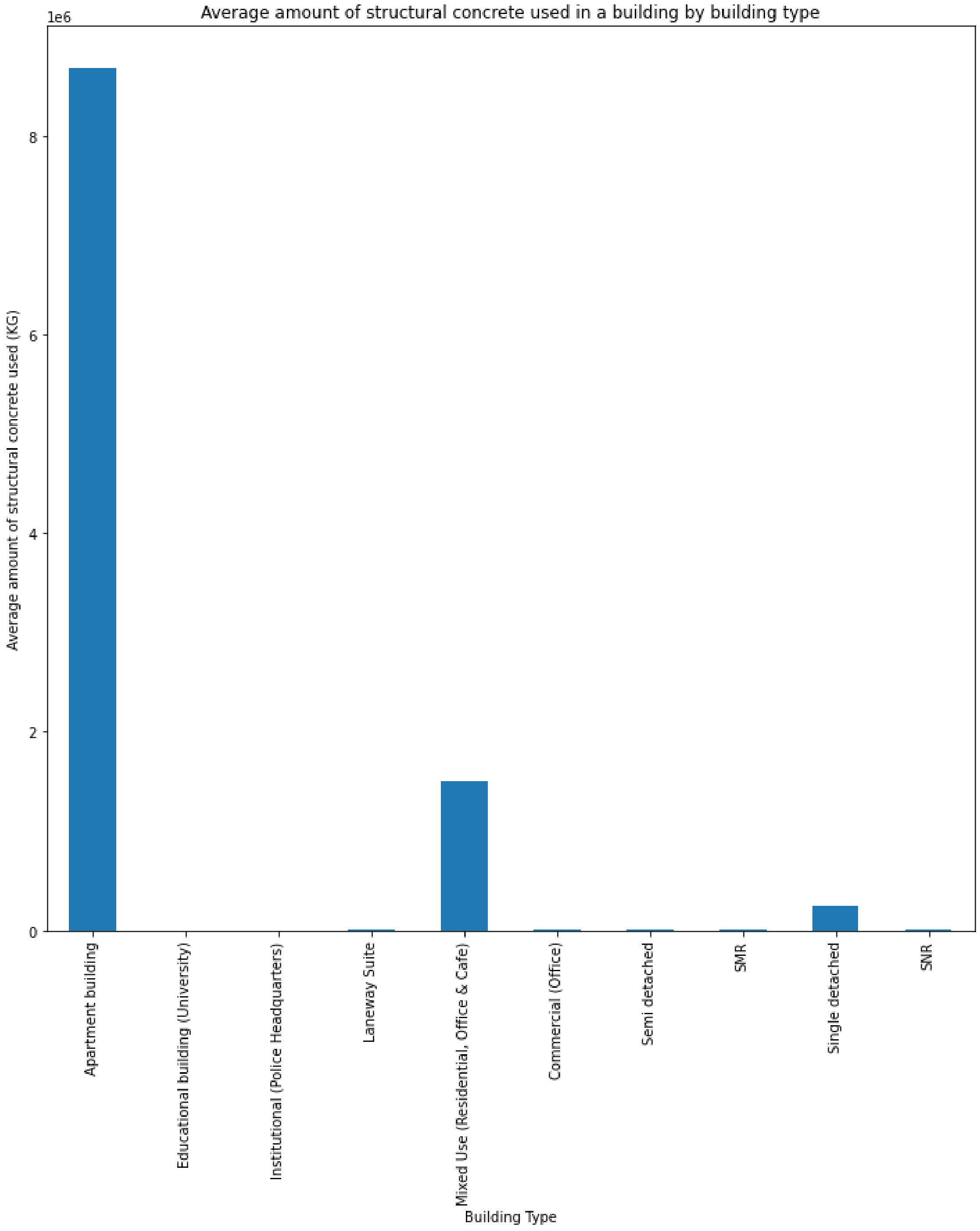
```
1988                                  0.000000               0.0
2007                                  0.000000               0.0
2009                                  0.000000               0.0
2011                                  0.000000               0.0
2016                                  0.000000          164112.0
2017                                  0.000000               0.0
2018                                  0.000000         1195248.0
2019                                  0.000000               0.0
2020                             282579.811429               0.0
2021                             323452.856389               0.0

[13 rows x 56 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␣
       ↪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': 1619,
          '2': 626,
          '4': 284,
          '1.1': 1619,
          '2.1': 626,
          '4.1': 284}),
 'OFF': Counter({'1': 494, '3': 307, '1.1': 494, '3.1': 307}),
 'APB': Counter({'1': 1149,
          '2': 1,
          '3': 970,
          '1.1': 1149,
          '2.1': 1,
          '3.1': 970}),
 'SMR': Counter({'1': 21, '2': 26, '4': 8, '1.1': 21, '2.1': 26, '4.1': 8}),
 'SNR': Counter({'1': 58, '2': 70, '4': 52, '1.1': 58, '2.1': 70, '4.1': 52}),
 'SMD': Counter({'1': 170,
          '2': 34,
          '4': 19,
          '1.1': 170,
          '2.1': 34,
          '4.1': 19}),
 'EDU': Counter({'1': 93, '3': 24, '1.1': 93, '3.1': 24, '2': 6, '2.1': 6}),
 'INS': Counter({'1': 90, '3': 77, '2': 1, '1.1': 90, '3.1': 77, '2.1': 1}),
 'MIX': Counter({'1': 363, '3': 276, '1.1': 363, '3.1': 276}),
 'LNW': Counter({'2': 46,
          '1': 142,
          '4': 18,
          '2.1': 46,
          '1.1': 142,
          '4.1': 18})}
```

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]:

```
                                        Gross Floor Area  Interiors/1  \
Building Type
Apartment building                              45505.41   10661289.6
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   11786352.0
Commercial (Office)                             52643.67          0.0
Semi detached                                     248.84          0.0
SMR                                               199.93          0.0
Single detached                                   478.40          0.0
SNR                                               302.76          0.0

                                        Services/1      Shell/1  Shell/2  \
Building Type
Apartment building                       3051024.0  43898236.80     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)   3756288.0  46126320.00     0.00
Commercial (Office)                            0.0         0.00     0.00
Semi detached                                  0.0      3728.53     0.00
SMR                                            0.0         0.00     0.00
Single detached                                0.0      3094.01    26.39
SNR                                            0.0      5009.89     0.00

                                        Sitework/1  \
Building Type
Apartment building                         46377.6
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

                                        Special Construction And Demolition/1  \
Building Type
Apartment building                                                   120633.6
Educational building (University)                                         0.0
Institutional (Police Headquarters)                                       0.0
Laneway Suite                                                             0.0
Mixed Use (Residential, Office & Cafe)                               124560.0
Commercial (Office)                                                       0.0
Semi detached                                                             0.0
SMR                                                                       0.0
Single detached                                                           0.0
SNR                                                                       0.0

                                        Substructure/1  Substructure/2
Building Type
Apartment building                         41078352.00            0.00
Educational building (University)                 0.00            0.00
Institutional (Police Headquarters)               0.00            0.00
Laneway Suite                                120136.29           89.61
Mixed Use (Residential, Office & Cafe)     23644704.00            0.00
Commercial (Office)                               0.00            0.00
Semi detached                                195281.69            0.00
SMR                                          220179.80        17801.72
Single detached                              362386.57        10695.74
SNR                                          186361.58        38668.55
```

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 (%)

                      1     2     3     4
Construction Date
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  0.03  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                       22.275983
1             389.24        0.0                       10.923878
2             411.64        0.0                        7.572148
3             269.56        0.0                       13.006958
6             445.99        0.0                       23.867021
7             438.45        0.0                       25.414390
8             714.07        0.0                       25.731860
9             343.24        0.0                        8.601238
12            226.89        0.0                       24.848490
13            611.73        0.0                       10.280399
14            343.44        0.0                       12.988933
15            613.38        0.0                       26.181048
18            178.38        0.0                       19.564876
19            323.80        0.0                       19.649137
20            837.56        0.0                       27.043696
21            587.86        0.0                       13.899565
22            568.21        0.0                       25.508574
24            294.84        0.0                        7.301085
25            496.77        0.0                       10.705970
27            643.30        0.0                       23.538085
28            701.61        0.0                       23.598185
30            378.70        0.0                       11.045477
31            324.16        0.0                       10.722348
32            533.53        0.0                       16.989813
34            423.03        0.0                       22.204039
35            328.16        0.0                       20.469873
36            421.59        0.0                       24.446345
37            628.59        0.0                       20.817516
```

```
38            464.51        0.0                         8.237491
40            346.14        0.0                        23.574161
42            891.97        0.0                        21.420624
43            525.61        0.0                        37.836980
44            502.87        0.0                        12.029172
45            379.18        0.0                        12.338604
46            549.65        0.0                        22.621422
48            393.82        0.0                        32.233722
49            648.14        0.0                        19.369512

    Exterior Vertical Enclosures  Foundations  …  Interior Finishes   \
0                     273.879246   671.298734  …          12.404160
1                     138.036505   562.637396  …           8.982520
2                     202.900740   928.924390  …           6.060738
3                     376.430391   510.718271  …           5.840963
6                     122.651951   590.233336  …           9.079800
7                     261.105842   538.936925  …           9.535021
8                     208.621020   553.834246  …           9.796603
9                     421.264481   567.787700  …          13.507767
12                    373.336551   523.749852  …           8.309207
13                    204.664017   687.428497  …          11.155739
14                    294.208560   848.199220  …          11.459760
15                    313.973141   597.075425  …          11.527797
18                    225.047421   742.299832  …          15.099686
19                    373.141002   297.539422  …           6.768110
20                    183.378773   635.166981  …          10.035389
21                    189.114111   856.370643  …           9.421087
22                    167.579773   510.025951  …          11.428838
24                    255.713013   522.549251  …           7.202727
25                    179.766287   503.451674  …           8.643960
27                    167.899386   312.730496  …          11.530390
28                    106.836046   532.328709  …          11.457562
30                    328.429793   807.205178  …          14.442118
31                    381.025836   755.707082  …           9.812179
32                    137.036860   618.125391  …           9.942594
34                    308.145095   487.215328  …           6.455055
35                    368.404312   777.488705  …           3.530982
36                    317.433015   848.887006  …           6.494623
37                    272.153180   739.489718  …           8.361186
38                    302.136065   825.690409  …          10.930098
40                    292.958678   575.128514  …          11.529474
42                    427.354429   490.411613  …          10.388085
43                    219.059867   996.020597  …          11.670402
44                    182.962148   557.359516  …           5.957241
45                    344.836007   782.607723  …           8.646680
46                    255.732337   532.936473  …           9.638352
48                    280.139019   377.960490  …          15.602610
```

```
49                    262.237167   694.374981  …           7.410405

    Plumbing  Site Improvements  Slabs-On-Grade  Special Construction  \
0        0.0                0.0      547.944803                   0.0
1        0.0                0.0      385.748930                   0.0
2        0.0                0.0      341.466712                   0.0
3        0.0                0.0      248.373052                   0.0
6        0.0                0.0      306.123236                   0.0
7        0.0                0.0      423.820216                   0.0
8        0.0                0.0      533.419152                   0.0
9        0.0                0.0      277.020456                   0.0
12       0.0                0.0      258.527086                   0.0
13       0.0                0.0      331.026308                   0.0
14       0.0                0.0      259.064497                   0.0
15       0.0                0.0      332.828674                   0.0
18       0.0                0.0      446.797277                   0.0
19       0.0                0.0      316.356228                   0.0
20       0.0                0.0      286.564536                   0.0
21       0.0                0.0      475.837937                   0.0
22       0.0                0.0      398.728694                   0.0
24       0.0                0.0      262.348369                   0.0
25       0.0                0.0      484.569517                   0.0
27       0.0                0.0      304.815828                   0.0
28       0.0                0.0      338.839280                   0.0
30       0.0                0.0      359.737791                   0.0
31       0.0                0.0      265.392494                   0.0
32       0.0                0.0      270.780577                   0.0
34       0.0                0.0      294.917900                   0.0
35       0.0                0.0      257.775680                   0.0
36       0.0                0.0      294.450482                   0.0
37       0.0                0.0      372.669095                   0.0
38       0.0                0.0      290.546806                   0.0
40       0.0                0.0      279.642162                   0.0
42       0.0                0.0      277.989207                   0.0
43       0.0                0.0      279.292555                   0.0
44       0.0                0.0      364.118658                   0.0
45       0.0                0.0      316.892098                   0.0
46       0.0                0.0      309.611427                   0.0
48       0.0                0.0      397.721411                   0.0
49       0.0                0.0      398.418928                   0.0

    Subgrade Enclosures  Substructure Interior  \
0             19.305806              15.043095
1             13.703909              23.742083
2             22.597144              16.554577
3              8.702931              40.140549
6             18.957284              11.151017
```

```
7              8.437842               3.634540
8             17.805246              50.385374
9             19.202489              15.489518
12             7.636806              19.065649
13            15.445508              12.336325
14            18.271059              11.202481
15             9.737016              18.008305
18             0.000000              17.516618
19             9.234013              23.892872
20            14.262339              17.750821
21            15.919505              18.196305
22            12.679302              22.419774
24            14.938095               7.790171
25            18.897377               8.309313
27             0.000000              23.013564
28            23.838920              17.579196
30            15.018237              21.150599
31            10.147984              16.619200
32            17.735736              26.870688
34             0.000000              20.026831
35             9.525678              38.173994
36            19.077879              25.667714
37            12.078412              14.286084
38            18.142034              24.971676
40            15.137569              24.023355
42             9.081839              21.450482
43            13.440870              16.550560
44            12.185477              21.757373
45            18.978312              27.501326
46            12.084458              16.691920
48            12.114254              11.723814
49            14.442444              16.480613

    Substructure Related Activities  Superstructure  Water And Gas Mitigation
0                               0.0       60.456007                       0.0
1                               0.0       52.543045                       0.0
2                               0.0       47.512572                       0.0
3                               0.0       60.793441                       0.0
6                               0.0       79.813025                       0.0
7                               0.0       79.814947                       0.0
8                               0.0       76.583183                       0.0
9                               0.0       70.741076                       0.0
12                              0.0       70.710629                       0.0
13                              0.0       66.776008                       0.0
14                              0.0       78.740032                       0.0
15                              0.0       81.917127                       0.0
18                              0.0      126.012088                       0.0
```

```
19                              0.0         73.194094                   0.0
20                              0.0         57.468451                   0.0
21                              0.0         74.915166                   0.0
22                              0.0         72.531075                   0.0
24                              0.0         60.778949                   0.0
25                              0.0         87.457857                   0.0
27                              0.0         70.786828                   0.0
28                              0.0         78.816226                   0.0
30                              0.0        164.784471                   0.0
31                              0.0         92.761405                   0.0
32                              0.0         50.939741                   0.0
34                              0.0         71.332214                   0.0
35                              0.0         98.568923                   0.0
36                              0.0         68.070763                   0.0
37                              0.0         94.130050                   0.0
38                              0.0         75.842867                   0.0
40                              0.0         55.480441                   0.0
42                              0.0         58.091063                   0.0
43                              0.0         66.530978                   0.0
44                              0.0         74.530550                   0.0
45                              0.0         93.720893                   0.0
46                              0.0         62.305655                   0.0
48                              0.0         99.798839                   0.0
49                              0.0         76.042092                   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]:
```
building_type_map = {
    'APB':'Mid to high-rise buildings',
    'EDU':'Mid to high-rise buildings',
    'INS':'Mid to high-rise buildings',
    'MIX':'Mid to high-rise buildings',
    'OFF':'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]:
```
set(df['Building Type'].values)
```

[40]:
```
{'APB', 'EDU', 'INS', 'LNW', 'MIX', 'OFF', 'SMD', 'SMR', 'SND', 'SNR'}
```

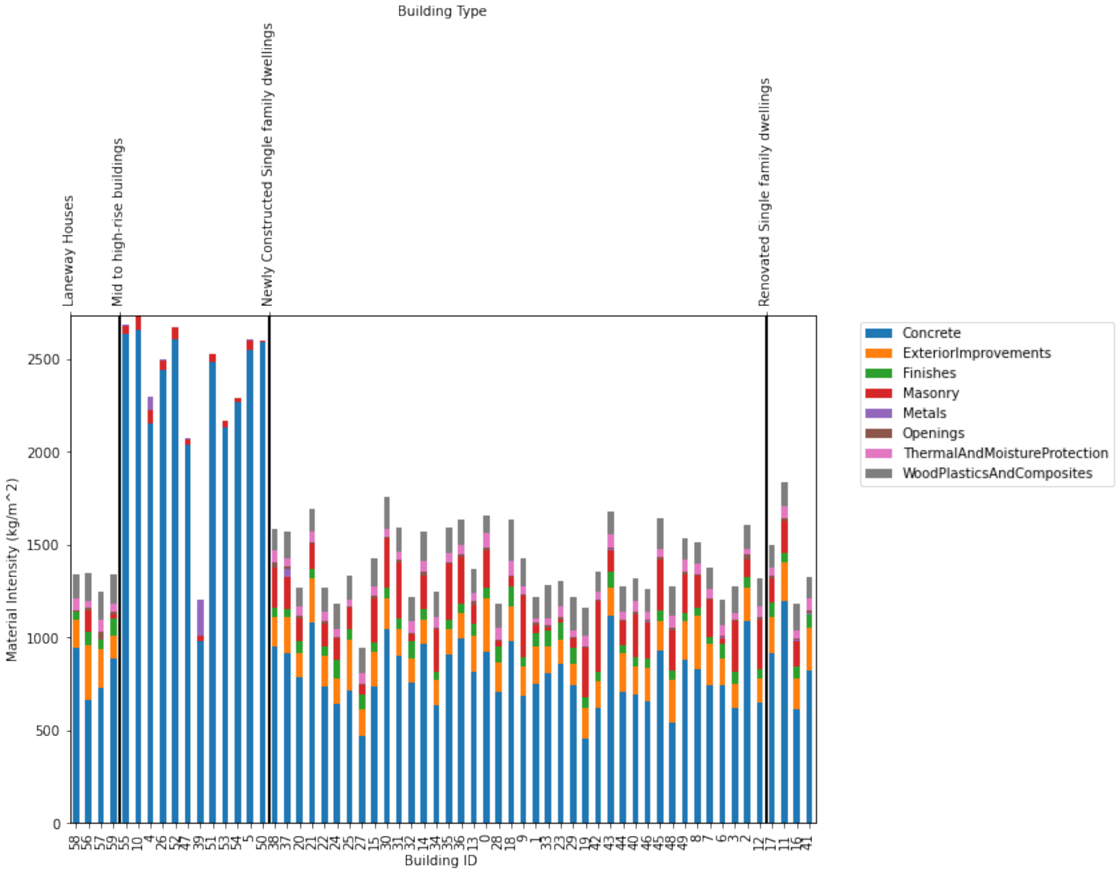
[41]:
```
fig, ax = plt.subplots(figsize=(10,7))

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()
```



[42]:
```
toplot['Total MI'] = toplot.iloc[:,6:].sum(axis=1)
```

[43]:
```
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:

                                           Gross Floor Area  Concrete  \
Building Type
Laneway Houses                                       150.01    804.14
Mid to high-rise buildings                         38097.44   2296.10
Newly Constructed Single family dwellings            461.18    793.42
Renovated Single family dwellings                    277.06    885.94

                                           ExteriorImprovements  Finishes  \
Building Type
```

```
Laneway Houses                                           194.18     64.80
Mid to high-rise buildings                                 0.00      0.00
Newly Constructed Single family dwellings                172.32     62.34
Renovated Single family dwellings                        200.60     67.28

                                           Masonry  Metals  Openings  \
Building Type
Laneway Houses                               35.65    0.26     19.24
Mid to high-rise buildings                   41.80   25.53      0.00
Newly Constructed Single family dwellings   167.55    1.92     11.98
Renovated Single family dwellings           110.62    1.48     11.67

                                           ThermalAndMoistureProtection  \
Building Type
Laneway Houses                                                    51.76
Mid to high-rise buildings                                         0.00
Newly Constructed Single family dwellings                         51.26
Renovated Single family dwellings                                 53.96

                                           WoodPlasticsAndComposites  Total MI
Building Type
Laneway Houses                                                149.97   1320.01
Mid to high-rise buildings                                      0.00   2363.42
Newly Constructed Single family dwellings                     137.64   1398.44
Renovated Single family dwellings                             129.17   1460.71
Std Dev Material Intensity:

                                           Gross Floor Area  Concrete  \
Building Type
Laneway Houses                                        62.86    130.35
Mid to high-rise buildings                         26125.17    466.31
Newly Constructed Single family dwellings            168.17    164.27
Renovated Single family dwellings                    117.28    240.52

                                           ExteriorImprovements  Finishes  \
Building Type
Laneway Houses                                            74.50     20.17
Mid to high-rise buildings                                 0.00      0.00
Newly Constructed Single family dwellings                 44.59     18.80
Renovated Single family dwellings                         25.87     12.77

                                           Masonry  Metals  Openings  \
Building Type
Laneway Houses                               55.08    0.52     18.17
Mid to high-rise buildings                   19.83   56.15      0.00
Newly Constructed Single family dwellings    98.51    6.70      4.41
Renovated Single family dwellings            75.76    1.72      2.85
```

```
                                          ThermalAndMoistureProtection  \
Building Type
Laneway Houses                                                   15.44
Mid to high-rise buildings                                        0.00
Newly Constructed Single family dwellings                        12.27
Renovated Single family dwellings                                10.87

                                          WoodPlasticsAndComposites  Total MI
Building Type
Laneway Houses                                                10.83     47.15
Mid to high-rise buildings                                     0.00    424.77
Newly Constructed Single family dwellings                     23.16    191.92
Renovated Single family dwellings                             13.09    280.04
```

[44]:

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

[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) * 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['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))

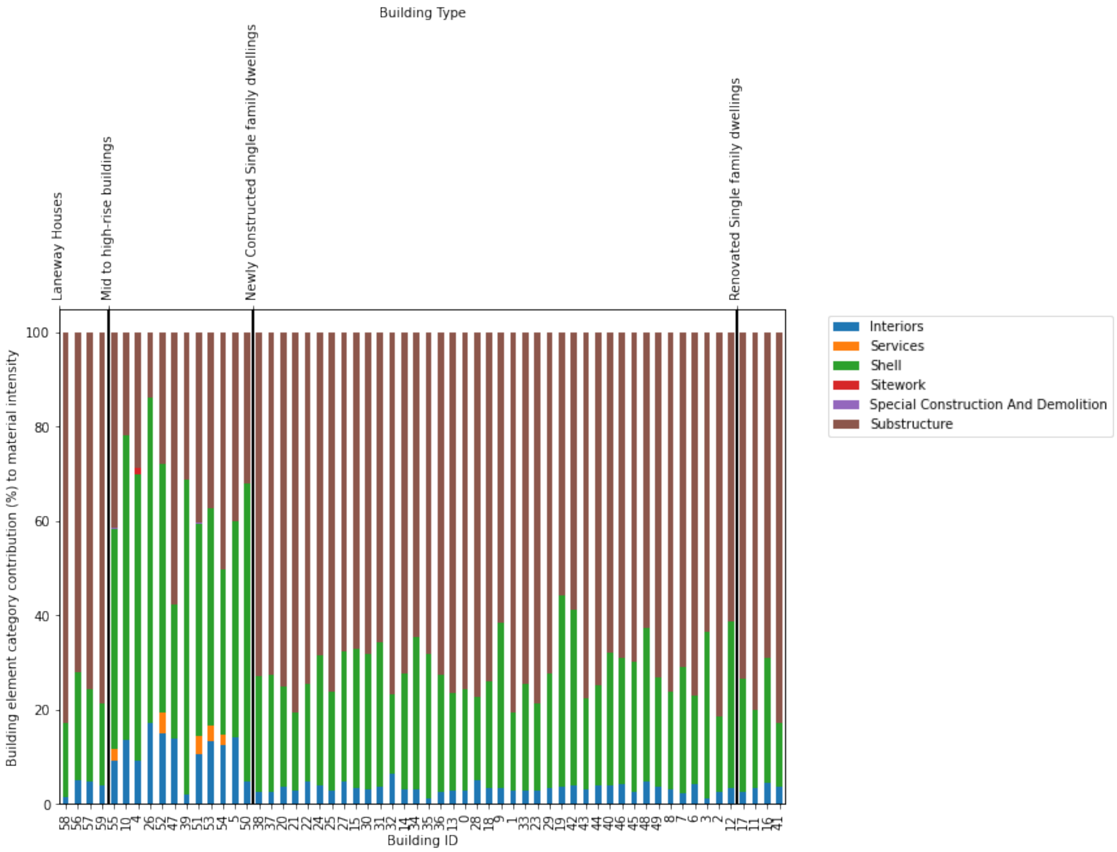
cmap = plt.get_cmap('tab10')

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()
```



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

```
[47]: 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')
```

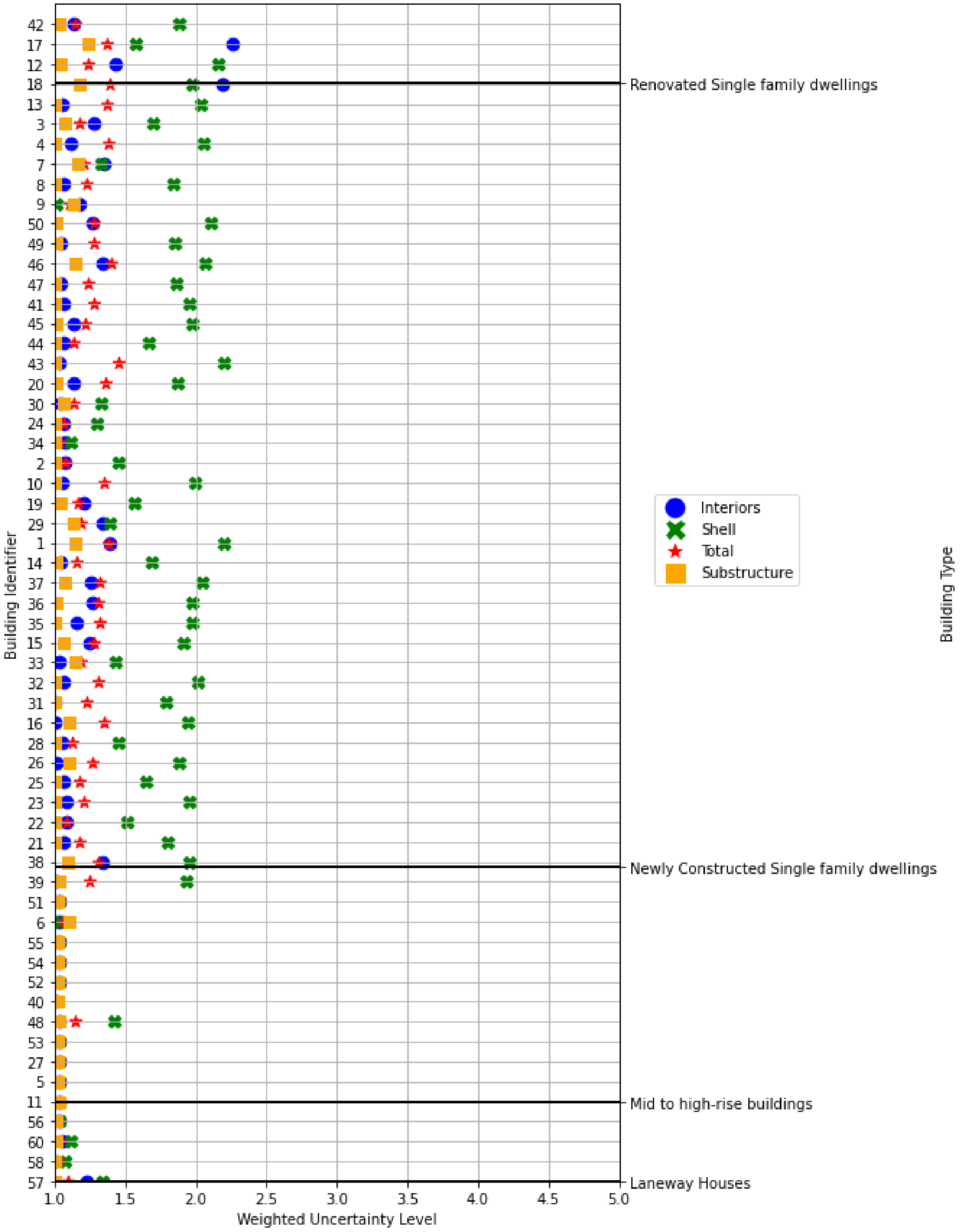
[48]:

```
# 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')
```

[49]:

```
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)
```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6
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52
40
48
53
27
5
11
56
60
58
57
Building Identifier
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Weighted Uncertainty Level
Renovated Single family dwellings
Newly Constructed Single family dwellings
Mid to high-rise buildings
Laneway Houses
Interiors
Shell
Total
Substructure
Building Type

[ ]: