# Sample

October 28, 2021

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

## 1 Helper functions

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

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

[3]:
```
df = pd.read_excel('../Dataset/dataset.xlsx',header=3,index_col=1)
df = df.drop('Unnamed: 0',axis=1).T#.reset_index().rename({'Building␣
↪Identifier':'index','index':'Building Identifier'},axis=1)
df = df[df.index.str.contains('0')]
```

[4]:
```
df[[c for c in df.columns if 'kg' in c]] = df[[c for c in df.columns if 'kg' in␣
↪c]].astype('float')
```

[5]:
```
df = pd.concat([df[headings].groupby(lambda x: x.split('.')[0],axis=0).
↪max(),df[[c for c in df.columns if 'kg' in c]].groupby(lambda x: x.split('.
↪')[0],axis=0).mean(numeric_only=True)],axis=1)
```

[6]:
```
name_conversion = pd.read_csv('name_conversion.csv')
building_name_conversion = pd.read_csv('building_type_name_conversion.csv')
```

[7]:
```
building_name_map = {k['Building Code']:k['Building Type'] for _,k in␣
↪building_name_conversion.iterrows()}
```

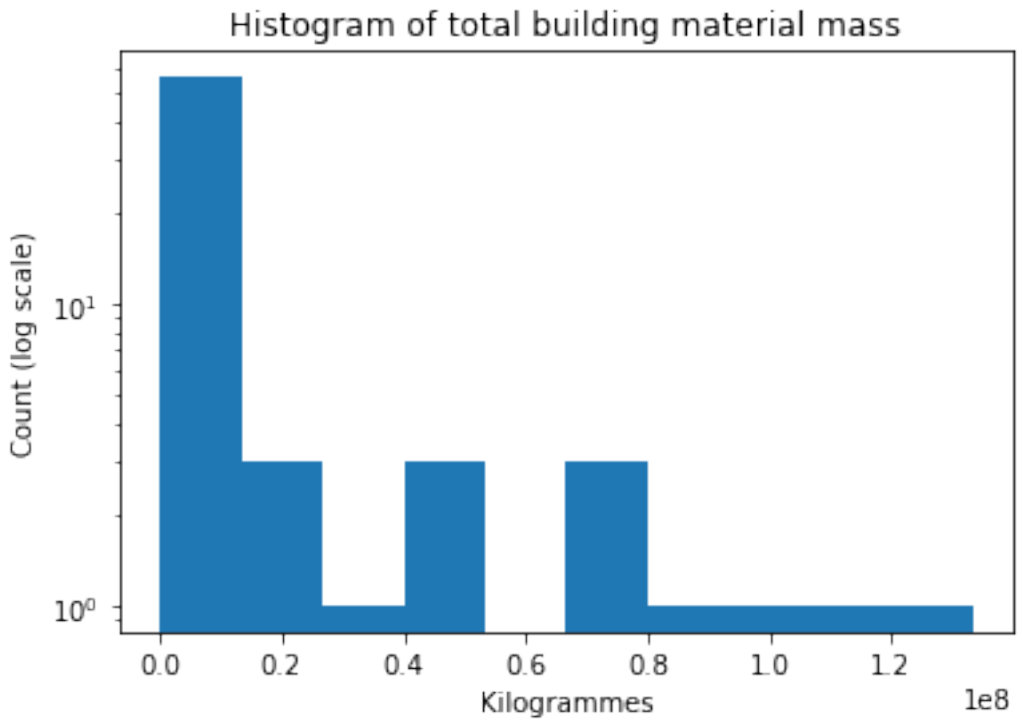
[8]:
```
name_map = {k.Code:k.Category for _,k in name_conversion.iterrows()}
```

[9]:
```
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':'0RT',
    'Roof Joists':'0RJ',
    'Parking Bumpers':'0PB',
    'Precast Concrete Stair Treads':'PCS',
    'Roof Curbs':'0RC',
    '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':'0RE',
    'Vegetated Low-Slope Roofing':'VLR',
    'Swimming Pools':'SWP',
    'Excavation Soil Anchors':'ESA',
    'Roof Window and Skylight Performance':'RWS',
    'Rainwater Storage Tanks':'RST',
    'Gray Water Tanks':'GWT'}.items()
}

additional_categories_map['0FT'] = 'Floor Trusses'
```

## 2 1. Plot sample figures

Here we plot building material mass.

[10]:
```
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.yscale('log')
plt.xlabel('Kilogrammes')
plt.ylabel('Count (log scale)');
```




## 3 2. Investigate a specific material

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

[11]:
```
cols = [d for d in df.columns if ('_03' in d or '_04 22' in d) and not '_03 20'␣
↪in d]
```

[12]:
```
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)
```

[13]:
```
concrete_df
```

[13]:

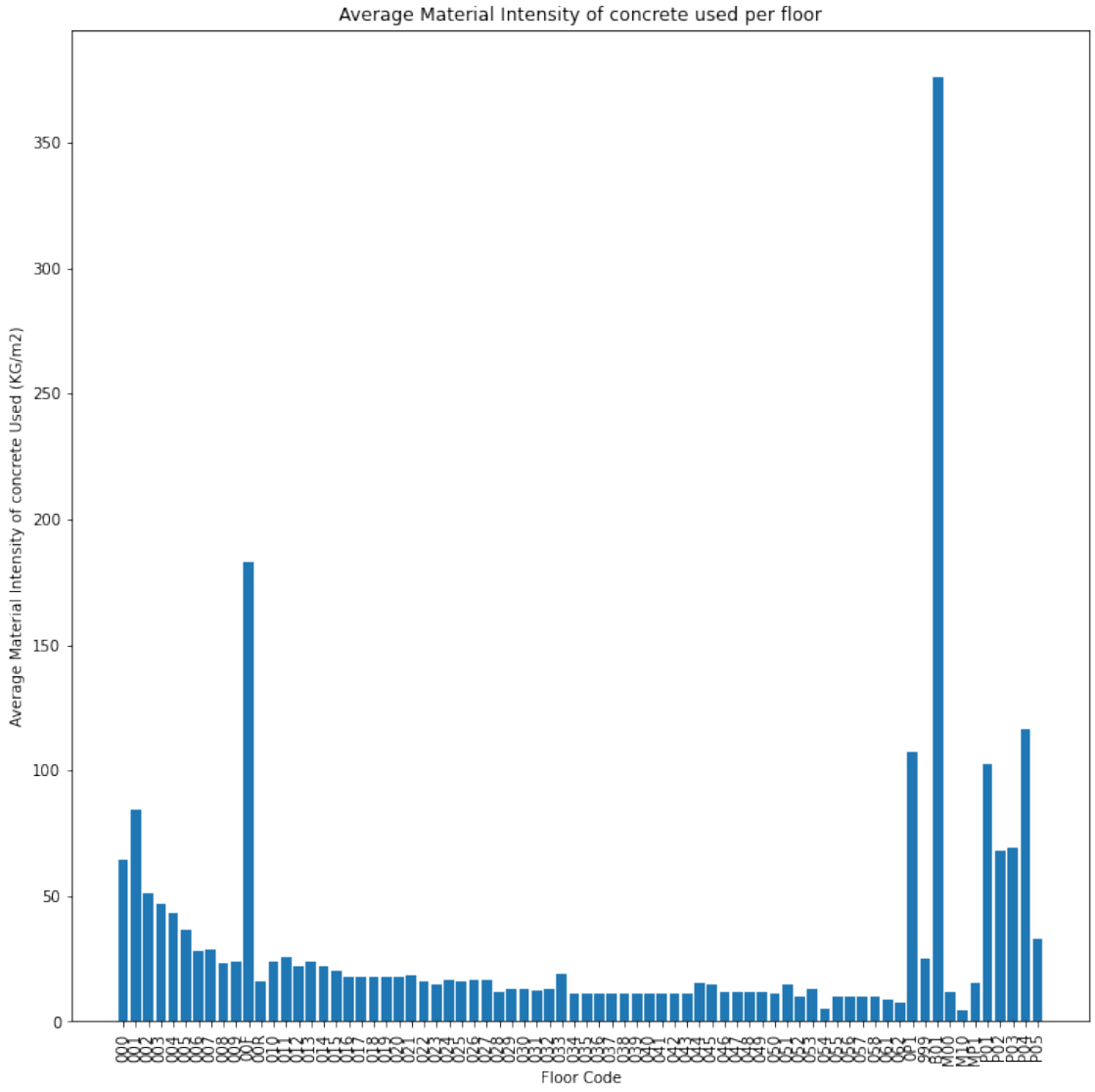
| Building Identifier | Country | City | Quality / Stage of Data | Construction Date | \ |
|---|---|---|---|---|---|
| 001 | CA | TOR | 00IFC | 2021 | |
| 002 | CA | TOR | 00IFC | 2021 | |
| 003 | CA | TOR | 00IFC | 2021 | |
| 004 | CA | TOR | 00IFC | 2021 | |
| 005 | CA | TOR | 00IFC | 2011 | |
| .. | … | … | … | … | |
| 066 | CA | TOR | 00IFT | 2020 | |
| 067 | CA | TOR | 00IFC | 2019 | |

```
068                      CA  TOR                   0IFBP              2021
069                      CA  TOR                   00IFC              2020
070                      CA  TOR                   00IFC              2021

Building Identifier Building Type  Gross Floor Area   Foundations  \
001                          SND            521.18  1.710150e+05
002                          SND            389.24  1.082862e+05
003                          SND            411.64  1.911912e+05
004                          SND            269.56  6.739916e+04
005                          OFF          11248.00  1.278753e+06
..                           …               …          …
066                          MIX          95769.00  1.566786e+07
067                          LNW            131.00  2.657254e+04
068                          LNW             71.00  2.721844e+04
069                          LNW             98.00  2.846246e+04
070                          LNW            131.00  3.930037e+03

Building Identifier  Subgrade Enclosures  Slabs-On-Grade  \
001                                0.000    6.751475e+04
002                                0.000    3.578757e+04
003                                0.000    3.254672e+04
004                                0.000    1.618022e+04
005                          1027239.110    6.846302e+05
..                                 …            …
066                          3484448.795    1.395514e+06
067                                0.000    2.924485e+04
068                                0.000    2.206696e+04
069                                0.000    1.264324e+04
070                                0.000    1.647018e+04

Building Identifier  Substructure Interior  Water And Gas Mitigation  \
001                          0.000000e+00                       0.0
002                          0.000000e+00                       0.0
003                          0.000000e+00                       0.0
004                          0.000000e+00                       0.0
005                          7.359709e+05                       0.0
..                                  …                         …
066                          1.368861e+07                       0.0
067                          0.000000e+00                       0.0
068                          0.000000e+00                       0.0
069                          0.000000e+00                       0.0
070                          0.000000e+00                       0.0

Building Identifier  Substructure Related Activities  Superstructure  \
001                                              0.0    1.949675e+03
002                                              0.0    1.409585e+03
003                                              0.0    1.562240e+02
```

```
004                                                0.0    2.269760e+01
005                                                0.0    7.126901e+06
..                                                 …             …
066                                                0.0    5.737703e+07
067                                                0.0    0.000000e+00
068                                                0.0    0.000000e+00
069                                                0.0    0.000000e+00
070                                                0.0    0.000000e+00

Building Identifier  Exterior Vertical Enclosures  \
001                                          0.00
002                                          0.00
003                                          0.00
004                                          0.00
005                                     311760.72
..                                            …
066                                      71331.23
067                                          0.00
068                                          0.00
069                                          0.00
070                                          0.00

Building Identifier  Exterior Horizontal Enclosures  Interior Construction  \
001                                              0.0           0.000000e+00
002                                              0.0           0.000000e+00
003                                              0.0           0.000000e+00
004                                              0.0           0.000000e+00
005                                            552.0           1.175564e+06
..                                               …                      …
066                                              0.0           1.463901e+07
067                                              0.0           0.000000e+00
068                                              0.0           0.000000e+00
069                                              0.0           0.000000e+00
070                                              0.0           0.000000e+00

Building Identifier    Conveying  Plumbing  Special Construction  \
001                        0.000       0.0                 0.000
002                        0.000       0.0                 0.000
003                        0.000       0.0                 0.000
004                        0.000       0.0                 0.000
005                        0.000       0.0                 0.000
..                           …         …                     …
066                  8273703.915       0.0            711760.625
067                        0.000       0.0                 0.000
068                        0.000       0.0                 0.000
069                        0.000       0.0                 0.000
070                        0.000       0.0                 0.000
```

```
Building Identifier  Site Improvements
001                                0.0000
002                                0.0000
003                                0.0000
004                                0.0000
005                           169830.9495
..                                    …
066                                0.0000
067                                0.0000
068                                0.0000
069                                0.0000
070                                0.0000

[70 rows x 20 columns]
```

[14]:
```
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 concrete used per floor')
plt.ylabel('Average Material Intensity of concrete Used (KG/m2)')
plt.xlabel('Floor Code');
```




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

[15]:
```
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()
```

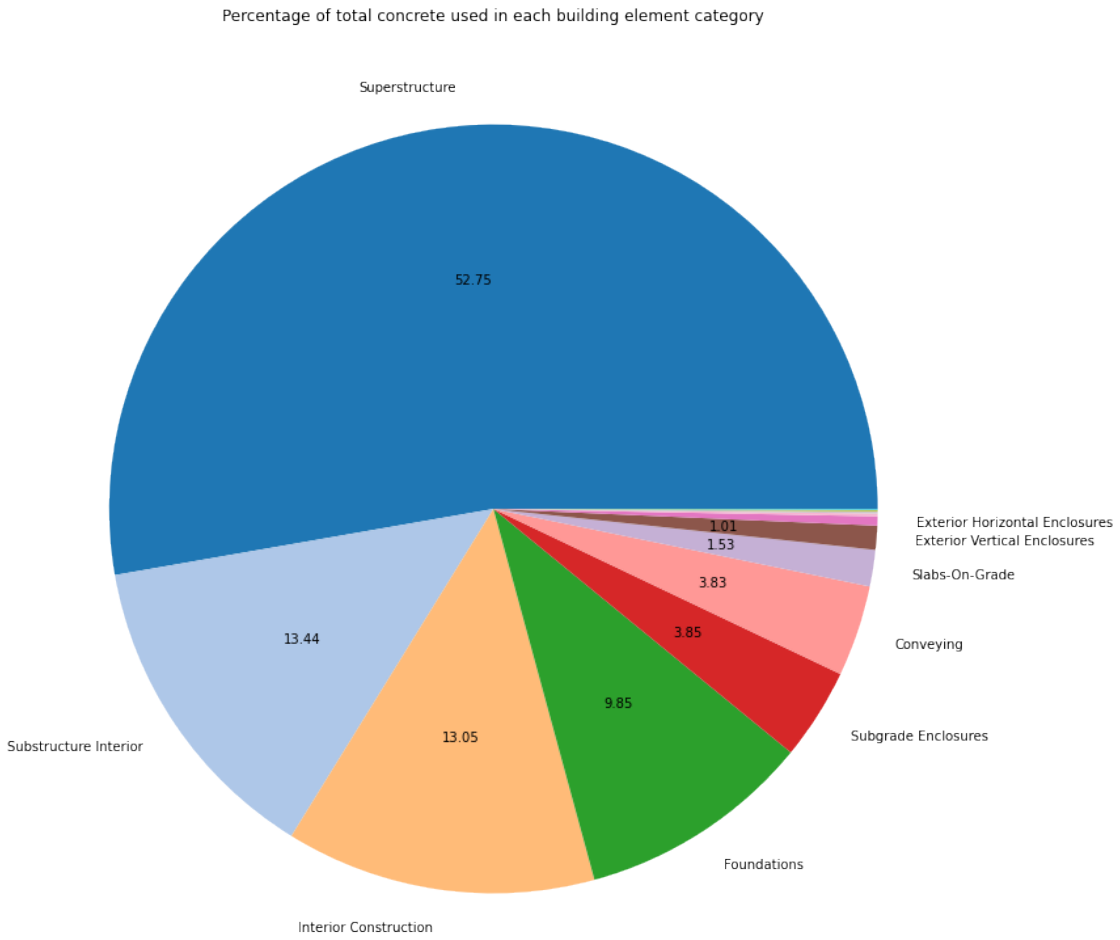
[16]:
```
concrete_df.mean().sort_values(ascending=False)
```

[16]:
```
Building Identifier
Superstructure                  6.844172e+06
Substructure Interior           1.743091e+06
Interior Construction           1.692972e+06
```

```
Foundations                          1.277363e+06
Subgrade Enclosures                  4.997662e+05
Conveying                            4.970189e+05
Slabs-On-Grade                       1.989609e+05
Exterior Vertical Enclosures         1.306903e+05
Exterior Horizontal Enclosures       5.030072e+04
Special Construction                 1.543692e+04
Substructure Related Activities      1.208292e+04
Site Improvements                    5.666442e+03
Plumbing                             5.186825e+03
Water And Gas Mitigation             1.219826e+03
dtype: float64
```

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

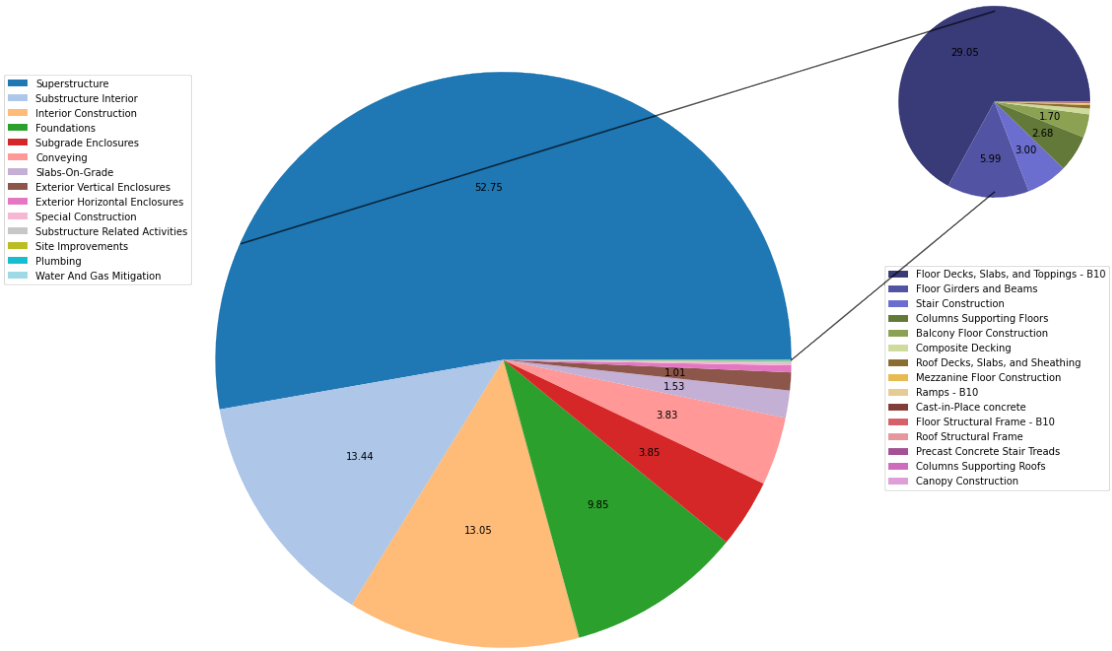
[17]:
```
def my_autopct(pct):
    return ('%.2f' % pct) if pct > 1 else ''
to_plot = concrete_df.mean().sort_values(ascending=False)
to_plot.plot.pie(figsize=(12,12),colormap='tab20',autopct=my_autopct,labels=[k␣
 ↪if v > 35000 else '' for k,v in to_plot.items()])
plt.ylabel('')
plt.title('Percentage of total concrete used in each building element␣
 ↪category');
# plt.legend(loc='center left',bbox_to_anchor=(-0.20, 0.75));
plt.tight_layout();
```




### 3.2 Pie version B: external legend with slice labels

[18]:
```
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='tab20b',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.

[19]:
```
mf_codes = pd.read_csv('mf_name_conversion.csv')
```

[20]:
```
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)]
```

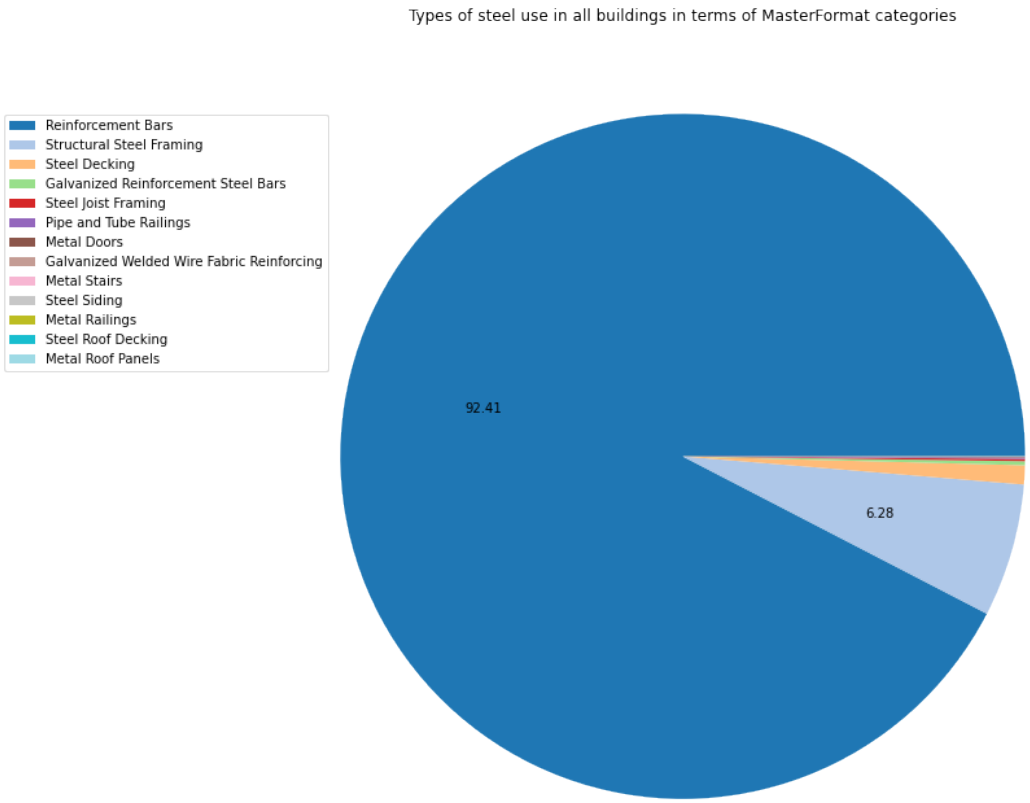
[21]:
```
columns_to_keep = []
for column in df.columns:
    if 'kg' in column:
        code = re.split('_',column)[2]
        for k,c in steel_codes.values:
            if c in code:
                columns_to_keep.append(column)
```

[22]:
```
f = lambda x: mf_codes[mf_codes.Code == str.replace(re.split('_',x)[2],'00','').
 ↪split('.')[0]].values[0][0]
steel_df = df[columns_to_keep].groupby(f,axis=1).sum()
```

[23]:
```
(steel_df>0).sum(axis=1).sort_values()
```

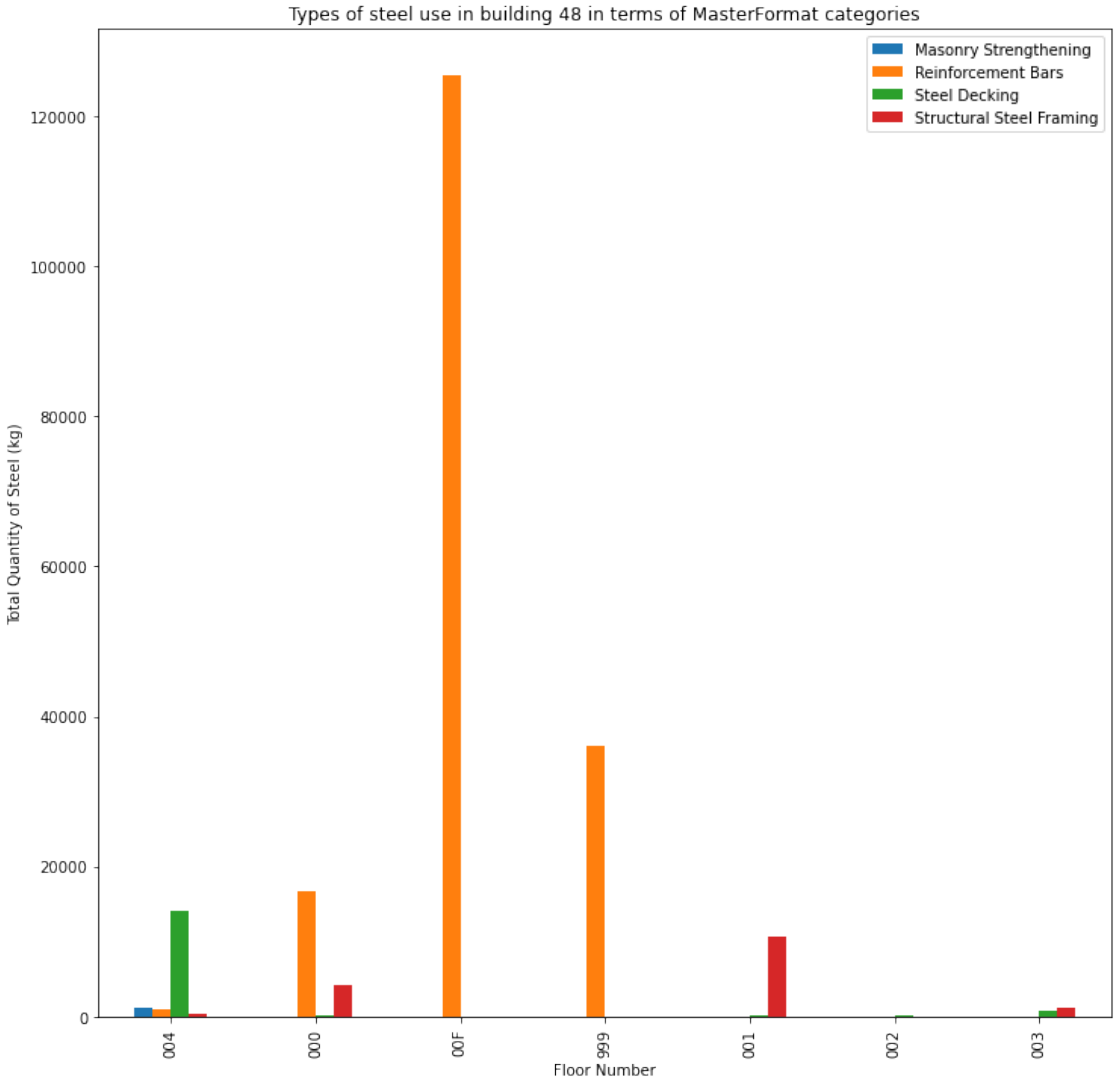
[23]:
```
035    1
067    1
066    1
023    1
036    1
      ..
058    4
049    4
050    4
020    4
048    4
Length: 70, dtype: int64
```

[24]:
```
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')
```




[25]:
```
f = lambda x: mf_codes[mf_codes.Code.str.contains(str.replace(re.
 ↪split('_',x)[2],'00','').split('.')[0].strip())].values[0][0] + '/' + x.
 ↪split('_')[0]
tdf = df[columns_to_keep].groupby(f,axis=1).sum().iloc[47,:]
tdf = tdf[tdf>0]
```

[26]:
```
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:

[27]:
```
concrete_df = pd.concat([df[headings[1:]],df[cols].groupby(f,axis=1).
↪sum()],axis=1)
concrete_df.groupby('Construction Date').mean()
```

[27]:
```
                  Building Identifier  Gross Floor Area  Cast Decks and Underlayment/002  \
Construction Date
1913                                                161.080000                                0.0
1917                                                199.930000                                0.0
1969                                                373.605000                                0.0
1988                                              21934.000000                                0.0
2007                                              73600.000000                                0.0
2009                                              73083.000000                                0.0
```

| | | |
|---|---|---|
| 2011 | 11282.500000 | 54943.2 |
| 2016 | 26841.666667 | 0.0 |
| 2017 | 35280.510000 | 0.0 |
| 2018 | 43365.090000 | 0.0 |
| 2019 | 107.050000 | 0.0 |
| 2020 | 10236.270000 | 0.0 |
| 2021 | 427.277895 | 0.0 |
| 2025 | 112537.000000 | 0.0 |

| Building Identifier | Cast Decks and Underlayment/003 \ |
|---|---|
| Construction Date | |
| 1913 | 0.0 |
| 1917 | 0.0 |
| 1969 | 0.0 |
| 1988 | 0.0 |
| 2007 | 0.0 |
| 2009 | 0.0 |
| 2011 | 65145.6 |
| 2016 | 0.0 |
| 2017 | 0.0 |
| 2018 | 0.0 |
| 2019 | 0.0 |
| 2020 | 0.0 |
| 2021 | 0.0 |
| 2025 | 0.0 |

| Building Identifier | Cast Decks and Underlayment/999 \ |
|---|---|
| Construction Date | |
| 1913 | 0.000000e+00 |
| 1917 | 0.000000e+00 |
| 1969 | 0.000000e+00 |
| 1988 | 0.000000e+00 |
| 2007 | 1.329816e+06 |
| 2009 | 0.000000e+00 |
| 2011 | 0.000000e+00 |
| 2016 | 0.000000e+00 |
| 2017 | 2.587372e+04 |
| 2018 | 0.000000e+00 |
| 2019 | 0.000000e+00 |
| 2020 | 0.000000e+00 |
| 2021 | 0.000000e+00 |
| 2025 | 0.000000e+00 |

| Building Identifier | Cast-in-Place Concrete/000 | Cast-in-Place Concrete/001 \ |
|---|---|---|
| Construction Date | | |
| 1913 | 0.000000e+00 | 0.000000e+00 |
| 1917 | 0.000000e+00 | 0.000000e+00 |

| | | |
|---|---|---|
| 1969 | 0.000000e+00 | 0.000000e+00 |
| 1988 | 3.999773e+06 | 1.435583e+06 |
| 2007 | 0.000000e+00 | 0.000000e+00 |
| 2009 | 0.000000e+00 | 0.000000e+00 |
| 2011 | 0.000000e+00 | 0.000000e+00 |
| 2016 | 0.000000e+00 | 0.000000e+00 |
| 2017 | 0.000000e+00 | 0.000000e+00 |
| 2018 | 0.000000e+00 | 0.000000e+00 |
| 2019 | 0.000000e+00 | 0.000000e+00 |
| 2020 | 0.000000e+00 | 0.000000e+00 |
| 2021 | 0.000000e+00 | 0.000000e+00 |
| 2025 | 0.000000e+00 | 0.000000e+00 |

| Building Identifier<br>Construction Date | Cast-in-Place Concrete/002 | Cast-in-Place Concrete/003 |
|---|---|---|
| 1913 | 0.000000e+00 | 0.000000e+00 |
| 1917 | 0.000000e+00 | 0.000000e+00 |
| 1969 | 0.000000e+00 | 0.000000e+00 |
| 1988 | 1.502795e+06 | 1.423554e+06 |
| 2007 | 0.000000e+00 | 0.000000e+00 |
| 2009 | 0.000000e+00 | 0.000000e+00 |
| 2011 | 0.000000e+00 | 0.000000e+00 |
| 2016 | 0.000000e+00 | 0.000000e+00 |
| 2017 | 0.000000e+00 | 0.000000e+00 |
| 2018 | 0.000000e+00 | 0.000000e+00 |
| 2019 | 0.000000e+00 | 0.000000e+00 |
| 2020 | 0.000000e+00 | 0.000000e+00 |
| 2021 | 0.000000e+00 | 0.000000e+00 |
| 2025 | 0.000000e+00 | 0.000000e+00 |

| Building Identifier<br>Construction Date | Cast-in-Place Concrete/004 | Cast-in-Place Concrete/005 |
|---|---|---|
| 1913 | 0.000000e+00 | 0.000000 |
| 1917 | 0.000000e+00 | 0.000000 |
| 1969 | 0.000000e+00 | 0.000000 |
| 1988 | 1.318964e+06 | 788129.689933 |
| 2007 | 0.000000e+00 | 0.000000 |
| 2009 | 0.000000e+00 | 0.000000 |
| 2011 | 0.000000e+00 | 0.000000 |
| 2016 | 0.000000e+00 | 0.000000 |
| 2017 | 0.000000e+00 | 0.000000 |
| 2018 | 0.000000e+00 | 0.000000 |
| 2019 | 0.000000e+00 | 0.000000 |
| 2020 | 0.000000e+00 | 0.000000 |
| 2021 | 0.000000e+00 | 0.000000 |
| 2025 | 0.000000e+00 | 0.000000 |

| Building Identifier … | Structural Concrete/999 | Structural Concrete/B01 \ |
|---|---|---|
| Construction Date … | | |
| 1913 … | 0.0 | 64035.190000 |
| 1917 … | 0.0 | 114018.460000 |
| 1969 … | 0.0 | 132278.015000 |
| 1988 … | 0.0 | 0.000000 |
| 2007 … | 0.0 | 0.000000 |
| 2009 … | 0.0 | 0.000000 |
| 2011 … | 0.0 | 0.000000 |
| 2016 … | 156360.0 | 0.000000 |
| 2017 … | 205476.0 | 0.000000 |
| 2018 … | 593112.0 | 0.000000 |
| 2019 … | 0.0 | 47353.684083 |
| 2020 … | 34108.8 | 98902.934000 |
| 2021 … | 0.0 | 156066.475284 |
| 2025 … | 847704.0 | 0.000000 |

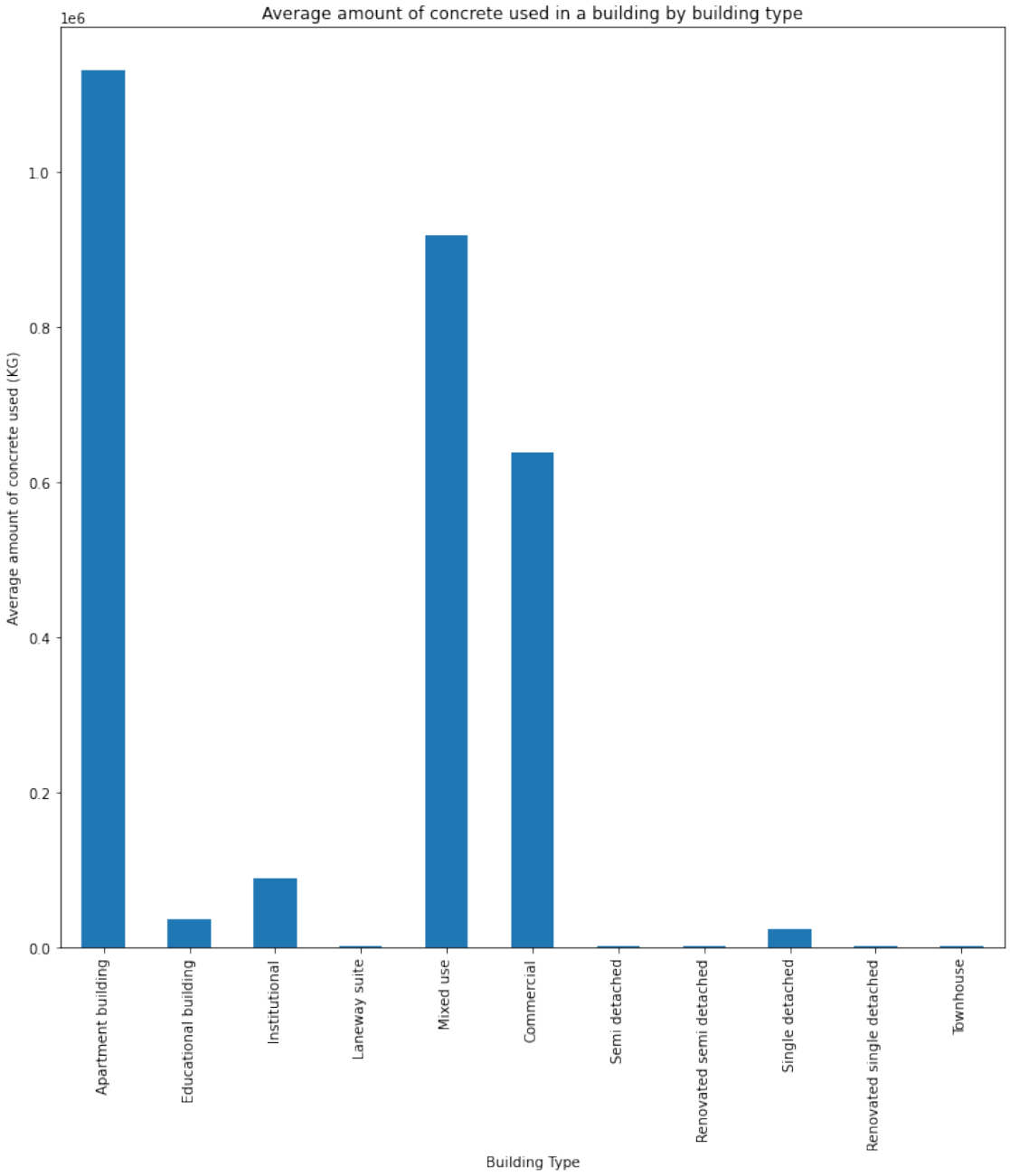
| Building Identifier | Structural Concrete/M00 | Structural Concrete/M10 \ |
|---|---|---|
| Construction Date | | |
| 1913 | 0.0 | 0.0 |
| 1917 | 0.0 | 0.0 |
| 1969 | 0.0 | 0.0 |
| 1988 | 0.0 | 0.0 |
| 2007 | 0.0 | 0.0 |
| 2009 | 0.0 | 0.0 |
| 2011 | 0.0 | 0.0 |
| 2016 | 141136.0 | 0.0 |
| 2017 | 0.0 | 0.0 |
| 2018 | 633824.0 | 0.0 |
| 2019 | 0.0 | 0.0 |
| 2020 | 65894.4 | 0.0 |
| 2021 | 0.0 | 0.0 |
| 2025 | 0.0 | 391968.0 |

| Building Identifier | Structural Concrete/MP1 | Structural Concrete/P01 \ |
|---|---|---|
| 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 | 1471112.0 |
| 2017 | 0.0 | 2764302.0 |
| 2018 | 0.0 | 2899816.0 |
| 2019 | 0.0 | 0.0 |

```
2020                                    0.0                 610046.4
2021                                    0.0                      0.0
2025                              1405272.0                7396368.0

Building Identifier  Structural Concrete/P02  Structural Concrete/P03  \
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                              1143352.0                1064296.0
2017                              2067108.0                2037768.0
2018                              2405792.0                1837944.0
2019                                    0.0                      0.0
2020                               468100.8                 466708.8
2021                                    0.0                      0.0
2025                              5522424.0                4559496.0

Building Identifier  Structural Concrete/P04  Structural Concrete/P05
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                              6087984.0                      0.0
2017                              1602108.0                 609738.0
2018                              2728856.0                      0.0
2019                                    0.0                      0.0
2020                              1820392.8                      0.0
2021                                    0.0                      0.0
2025                              6789888.0                      0.0

[14 rows x 319 columns]
```

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

[28]:
```
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 concrete used (KG)')
plt.title('Average amount of 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.

[29]:
```
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])
```

[30]:
```
from collections import Counter
```

[31]:
```
for k,v in uncertainty_level.items():
    uncertainty_level[k] = Counter(v) #Construct a Counter object per building␣
 ↪type
```

[32]:
```
uncertainty_level
```

[32]:
```
{'SND': Counter({'3': 626, '2': 1582, '5': 284}),
 'OFF': Counter({'2': 491, '4': 307}),
 'APB': Counter({'2': 1844, '3': 1, '4': 1596}),
 'SMR': Counter({'2': 20, '3': 26, '5': 8}),
 'SNR': Counter({'2': 55, '3': 70, '5': 52}),
 'SMD': Counter({'2': 167, '3': 34, '5': 19}),
 'EDU': Counter({'2': 91, '4': 24, '3': 6}),
 'INS': Counter({'4': 77, '2': 89, '3': 1}),
 'MIX': Counter({'2': 1262, '4': 1047}),
 'LNW': Counter({'3': 92, '2': 287, '5': 21}),
 'TWN': Counter({'2': 58, '4': 6})}
```

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

[33]:
```
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)
```

[34]:
```
by_function_df.groupby('Building Type').mean().rename(index=building_name_map).
 ↪drop(['Construction Date'],axis=1).round(2)
```

[34]:

| Building Type | Building Identifier | Gross Floor Area | Interiors/2 | Interiors/3 | \ |
|---|---|---|---|---|---|
| Apartment building | | 39160.26 | 5624203.35 | 0.00 | |
| Educational building | | 7901.00 | 480382.15 | 3096.66 | |
| Institutional | | 21934.00 | 1295281.75 | 0.00 | |
| Laneway suite | | 128.88 | 0.00 | 0.00 | |
| Mixed use | | 80760.42 | 12716484.57 | 0.00 | |
| Commercial | | 52643.67 | 9898215.44 | 0.00 | |

| | | | |
|---|---|---|---|
| Semi detached | 248.84 | 0.00 | 0.00 |
| Renovated semi detached | 199.93 | 0.00 | 0.00 |
| Single detached | 478.40 | 0.00 | 0.00 |
| Renovated single detached | 302.76 | 0.00 | 68.77 |
| Townhouse | 3566.00 | 0.00 | 0.00 |

| Building Identifier<br>Building Type | Interiors/4 | Services/2 | Services/4 | Shell/2 |
|---|---|---|---|---|
| Apartment building | 171337.00 | 1529274.0 | 50074.69 | 20886862.84 |
| Educational building | 14080.27 | 0.0 | 0.00 | 1520252.59 |
| Institutional | 40860.46 | 0.0 | 0.00 | 17371405.92 |
| Laneway suite | 0.00 | 0.0 | 0.00 | 0.00 |
| Mixed use | 370412.46 | 7268736.0 | 237801.46 | 51743951.21 |
| Commercial | 285637.96 | 0.0 | 0.00 | 43308969.36 |
| Semi detached | 0.00 | 0.0 | 0.00 | 1866.95 |
| Renovated semi detached | 0.00 | 0.0 | 0.00 | 0.00 |
| Single detached | 0.00 | 0.0 | 0.00 | 1549.49 |
| Renovated single detached | 0.00 | 0.0 | 0.00 | 2504.95 |
| Townhouse | 0.00 | 0.0 | 0.00 | 0.00 |

| Building Identifier<br>Building Type | Shell/3 | Shell/4 | Shell/5 | Sitework/2 |
|---|---|---|---|---|
| Apartment building | 0.00 | 761128.06 | 0.00 | 14493.0 |
| Educational building | 834695.64 | 7713.03 | 0.00 | 0.0 |
| Institutional | 0.00 | 656655.11 | 0.00 | 0.0 |
| Laneway suite | 0.00 | 0.00 | 0.00 | 0.0 |
| Mixed use | 0.00 | 1909970.03 | 0.00 | 0.0 |
| Commercial | 0.00 | 1621345.80 | 0.00 | 89288.0 |
| Semi detached | 5.41 | 0.00 | 0.00 | 0.0 |
| Renovated semi detached | 40.11 | 0.00 | 0.00 | 0.0 |
| Single detached | 22.18 | 0.00 | 0.93 | 0.0 |
| Renovated single detached | 6.65 | 0.00 | 0.00 | 0.0 |
| Townhouse | 0.00 | 0.00 | 0.00 | 0.0 |

| Building Identifier<br>Building Type | Sitework/4 | Special Construction And Demolition/2 |
|---|---|---|
| Apartment building | 474.04 | 37698.0 |
| Educational building | 0.00 | 0.0 |
| Institutional | 0.00 | 0.0 |
| Laneway suite | 0.00 | 0.0 |
| Mixed use | 0.00 | 249760.0 |
| Commercial | 3016.86 | 0.0 |
| Semi detached | 0.00 | 0.0 |
| Renovated semi detached | 0.00 | 0.0 |
| Single detached | 0.00 | 0.0 |
| Renovated single detached | 0.00 | 0.0 |
| Townhouse | 0.00 | 0.0 |

| Building Identifier | Special Construction And Demolition/4 |
|---|---|
| Building Type | |
| Apartment building | 339.88 |
| Educational building | 0.00 |
| Institutional | 0.00 |
| Laneway suite | 0.00 |
| Mixed use | 9000.47 |
| Commercial | 0.00 |
| Semi detached | 0.00 |
| Renovated semi detached | 0.00 |
| Single detached | 0.00 |
| Renovated single detached | 0.00 |
| Townhouse | 0.00 |

| Building Identifier | Substructure/2 | Substructure/3 | Substructure/4 |
|---|---|---|---|
| Building Type | | | |
| Apartment building | 15661850.24 | 109212.00 | 365922.73 |
| Educational building | 2793438.68 | 0.00 | 91853.12 |
| Institutional | 8890567.75 | 0.00 | 239579.15 |
| Laneway suite | 48858.34 | 2104.66 | 0.00 |
| Mixed use | 22801051.57 | 0.00 | 645320.97 |
| Commercial | 12411535.27 | 0.00 | 354767.84 |
| Semi detached | 97751.05 | 7.78 | 0.00 |
| Renovated semi detached | 110261.75 | 8921.68 | 0.00 |
| Single detached | 181911.50 | 5413.20 | 0.00 |
| Renovated single detached | 93196.84 | 19429.34 | 0.00 |
| Townhouse | 534318.99 | 0.00 | 14428.09 |

| Building Identifier | Substructure/5 |
|---|---|
| Building Type | |
| Apartment building | 0.00 |
| Educational building | 0.00 |
| Institutional | 0.00 |
| Laneway suite | 0.65 |
| Mixed use | 0.00 |
| Commercial | 0.00 |
| Semi detached | 6.93 |
| Renovated semi detached | 0.00 |
| Single detached | 38.46 |
| Renovated single detached | 0.00 |
| Townhouse | 0.00 |

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

[35]:
```
f = lambda x: x.split('_')[-1].split('.')[0] #Select only the uncertainty score.
print('Average amount of material used per building, by year and uncertainty␣
 ↪score (%)')
result = pd.concat([df['Construction Date'],df[[c for c in df.columns if 'kg'␣
 ↪in c]].groupby(f,axis=1).sum()],axis=1).groupby('Construction Date').mean()
for k,v in result.iterrows():
    result.loc[k,:] = v/v.sum()
display(result.round(2))
```

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

| Construction Date | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 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 | 0.96 | 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 | 0.98 | 0.02 | 0.00 | 0.00 |
| 2020 | 0.97 | 0.00 | 0.03 | 0.00 |
| 2021 | 0.78 | 0.09 | 0.00 | 0.13 |
| 2025 | 0.97 | 0.00 | 0.03 | 0.00 |

## 5 4. Material Intensity

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

[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)
```

[37]:
```
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']
```

[37]:

| Building Identifier | City | Quality / Stage of Data | Construction Date | \ |
|---|---|---|---|---|
| 001 | TOR | 00IFC | 2021 | |
| 002 | TOR | 00IFC | 2021 | |
| 003 | TOR | 00IFC | 2021 | |
| 004 | TOR | 00IFC | 2021 | |
| 007 | TOR | 00IFC | 2021 | |

| | | | |
|---|---|---|---|
| 008 | TOR | 00IFC | 2021 |
| 009 | TOR | 00IFC | 2021 |
| 010 | TOR | 00IFC | 2021 |
| 013 | TOR | 00IFC | 2021 |
| 014 | TOR | 00IFC | 2021 |
| 015 | TOR | 00IFC | 2021 |
| 016 | TOR | 00IFC | 2021 |
| 019 | TOR | 00IFC | 2021 |
| 020 | TOR | 00IFC | 2021 |
| 021 | TOR | 00IFC | 2020 |
| 022 | TOR | 00IFC | 2021 |
| 023 | TOR | 00IFC | 2021 |
| 025 | TOR | 00IFC | 2021 |
| 026 | TOR | 00IFC | 2021 |
| 028 | TOR | 00IFC | 2021 |
| 029 | TOR | 00IFC | 2021 |
| 031 | TOR | 00IFC | 2021 |
| 032 | TOR | 00IFC | 2021 |
| 033 | TOR | 00IFC | 2020 |
| 035 | TOR | 00IFC | 2021 |
| 036 | TOR | 00IFC | 2021 |
| 037 | TOR | 00IFC | 2021 |
| 038 | TOR | 00IFC | 2020 |
| 039 | TOR | 00IFC | 2021 |
| 041 | TOR | 00IFC | 2021 |
| 043 | TOR | 00IFC | 2021 |
| 044 | TOR | 00IFC | 2021 |
| 045 | TOR | 00IFC | 2021 |
| 046 | TOR | 00IFC | 2021 |
| 047 | TOR | 00IFC | 2021 |
| 049 | TOR | 00IFC | 2020 |
| 050 | TOR | 00IFC | 2021 |

| Building Identifier | Building Type | Gross Floor Area | Conveying | \ |
|---|---|---|---|---|
| 001 | SND | 521.18 | 0.0 | |
| 002 | SND | 389.24 | 0.0 | |
| 003 | SND | 411.64 | 0.0 | |
| 004 | SND | 269.56 | 0.0 | |
| 007 | SND | 445.99 | 0.0 | |
| 008 | SND | 438.45 | 0.0 | |
| 009 | SND | 714.07 | 0.0 | |
| 010 | SND | 343.24 | 0.0 | |
| 013 | SND | 226.89 | 0.0 | |
| 014 | SND | 611.73 | 0.0 | |
| 015 | SND | 343.44 | 0.0 | |
| 016 | SND | 613.38 | 0.0 | |
| 019 | SND | 178.38 | 0.0 | |

```
020                             SND             323.80        0.0
021                             SND             837.56        0.0
022                             SND             587.86        0.0
023                             SND             568.21        0.0
025                             SND             294.84        0.0
026                             SND             496.77        0.0
028                             SND             643.30        0.0
029                             SND             701.61        0.0
031                             SND             378.70        0.0
032                             SND             324.16        0.0
033                             SND             533.53        0.0
035                             SND             423.03        0.0
036                             SND             328.16        0.0
037                             SND             421.59        0.0
038                             SND             628.59        0.0
039                             SND             464.51        0.0
041                             SND             346.14        0.0
043                             SND             891.97        0.0
044                             SND             525.61        0.0
045                             SND             502.87        0.0
046                             SND             379.18        0.0
047                             SND             549.65        0.0
049                             SND             393.82        0.0
050                             SND             648.14        0.0

Building Identifier  Exterior Horizontal Enclosures  \
001                                        11.137992
002                                         5.461939
003                                         3.786074
004                                         6.503479
007                                        11.933511
008                                        12.707195
009                                        12.865930
010                                         4.300619
013                                        12.424245
014                                         5.140200
015                                         6.494467
016                                        13.090524
019                                         9.782438
020                                         9.824569
021                                        13.521848
022                                         6.949783
023                                        12.754287
025                                         3.650542
026                                         5.352985
028                                        11.769043
029                                        11.799093
```

| | |
|---|---|
| 031 | 5.522739 |
| 032 | 5.361174 |
| 033 | 8.494907 |
| 035 | 11.102019 |
| 036 | 10.234937 |
| 037 | 12.223172 |
| 038 | 10.408758 |
| 039 | 4.118745 |
| 041 | 11.787081 |
| 043 | 10.710312 |
| 044 | 18.918490 |
| 045 | 6.014586 |
| 046 | 6.169302 |
| 047 | 11.310711 |
| 049 | 16.116861 |
| 050 | 9.684756 |

| Building Identifier | Exterior Vertical Enclosures | Foundations | \ |
|---|---|---|---|
| 001 | 136.939623 | 335.649367 | |
| 002 | 69.018253 | 281.318698 | |
| 003 | 101.450370 | 464.462195 | |
| 004 | 188.215196 | 255.359136 | |
| 007 | 61.325975 | 295.116668 | |
| 008 | 130.552921 | 269.468463 | |
| 009 | 104.310510 | 276.917123 | |
| 010 | 210.632241 | 283.893850 | |
| 013 | 186.668275 | 261.874926 | |
| 014 | 102.332008 | 343.714248 | |
| 015 | 147.104280 | 424.099610 | |
| 016 | 156.986570 | 298.537712 | |
| 019 | 112.523711 | 371.149916 | |
| 020 | 186.570501 | 148.769711 | |
| 021 | 91.689386 | 317.583491 | |
| 022 | 94.557055 | 428.185321 | |
| 023 | 83.789887 | 255.012975 | |
| 025 | 127.856507 | 261.274626 | |
| 026 | 89.883144 | 251.725837 | |
| 028 | 83.949693 | 156.365248 | |
| 029 | 53.418023 | 266.164355 | |
| 031 | 164.214896 | 403.602589 | |
| 032 | 190.512918 | 377.853541 | |
| 033 | 68.518430 | 309.062696 | |
| 035 | 154.072547 | 243.607664 | |
| 036 | 184.202156 | 388.744353 | |
| 037 | 158.716507 | 424.443503 | |
| 038 | 136.076590 | 369.744859 | |
| 039 | 151.068033 | 412.845205 | |

| | | |
|---|---|---|
| 041 | 146.479339 | 287.564257 |
| 043 | 213.677214 | 245.205806 |
| 044 | 109.529933 | 498.010299 |
| 045 | 91.481074 | 278.679758 |
| 046 | 172.418003 | 391.303861 |
| 047 | 127.866168 | 266.468237 |
| 049 | 140.069509 | 188.980245 |
| 050 | 131.118584 | 347.187490 |

| Building Identifier | Interior Construction | Interior Finishes | Plumbing | \ |
|---|---|---|---|---|
| 001 | 16.482129 | 6.202080 | 0.0 | |
| 002 | 12.248343 | 4.491260 | 0.0 | |
| 003 | 15.931829 | 3.030369 | 0.0 | |
| 004 | 4.574132 | 2.920482 | 0.0 | |
| 007 | 19.773909 | 4.539900 | 0.0 | |
| 008 | 10.683759 | 4.767511 | 0.0 | |
| 009 | 18.937583 | 4.898301 | 0.0 | |
| 010 | 17.891930 | 6.753884 | 0.0 | |
| 013 | 17.256393 | 4.154604 | 0.0 | |
| 014 | 13.258982 | 5.577869 | 0.0 | |
| 015 | 18.195449 | 5.729880 | 0.0 | |
| 016 | 17.589067 | 5.763898 | 0.0 | |
| 019 | 19.638502 | 7.549843 | 0.0 | |
| 020 | 18.186467 | 3.384055 | 0.0 | |
| 021 | 17.799752 | 5.017694 | 0.0 | |
| 022 | 19.088554 | 4.710543 | 0.0 | |
| 023 | 23.268519 | 5.714419 | 0.0 | |
| 025 | 20.047035 | 3.601363 | 0.0 | |
| 026 | 14.370613 | 4.321980 | 0.0 | |
| 028 | 16.010229 | 5.765195 | 0.0 | |
| 029 | 23.078653 | 5.728781 | 0.0 | |
| 031 | 19.181898 | 7.221059 | 0.0 | |
| 032 | 24.166732 | 4.906090 | 0.0 | |
| 033 | 34.027695 | 4.971297 | 0.0 | |
| 035 | 16.390809 | 3.227528 | 0.0 | |
| 036 | 7.854953 | 1.765491 | 0.0 | |
| 037 | 16.125050 | 3.247311 | 0.0 | |
| 038 | 16.271010 | 4.180593 | 0.0 | |
| 039 | 15.108900 | 5.465049 | 0.0 | |
| 041 | 19.523228 | 5.764737 | 0.0 | |
| 043 | 20.691791 | 5.194042 | 0.0 | |
| 044 | 19.155639 | 5.835201 | 0.0 | |
| 045 | 22.485115 | 2.978621 | 0.0 | |
| 046 | 16.651076 | 4.323340 | 0.0 | |
| 047 | 20.753973 | 4.819176 | 0.0 | |
| 049 | 22.332639 | 7.801305 | 0.0 | |
| 050 | 23.995586 | 3.705203 | 0.0 | |

| Building Identifier | Site Improvements | Slabs-On-Grade | Special Construction | \ |
|---|---|---|---|---|
| 001 | 0.0 | 273.972401 | 0.0 | |
| 002 | 0.0 | 192.874465 | 0.0 | |
| 003 | 0.0 | 170.733356 | 0.0 | |
| 004 | 0.0 | 124.186526 | 0.0 | |
| 007 | 0.0 | 153.061618 | 0.0 | |
| 008 | 0.0 | 211.910108 | 0.0 | |
| 009 | 0.0 | 266.709576 | 0.0 | |
| 010 | 0.0 | 138.510228 | 0.0 | |
| 013 | 0.0 | 129.263543 | 0.0 | |
| 014 | 0.0 | 165.513154 | 0.0 | |
| 015 | 0.0 | 129.532248 | 0.0 | |
| 016 | 0.0 | 166.414337 | 0.0 | |
| 019 | 0.0 | 223.398638 | 0.0 | |
| 020 | 0.0 | 158.178114 | 0.0 | |
| 021 | 0.0 | 143.282268 | 0.0 | |
| 022 | 0.0 | 237.918968 | 0.0 | |
| 023 | 0.0 | 199.364347 | 0.0 | |
| 025 | 0.0 | 131.174185 | 0.0 | |
| 026 | 0.0 | 242.284758 | 0.0 | |
| 028 | 0.0 | 152.407914 | 0.0 | |
| 029 | 0.0 | 169.419640 | 0.0 | |
| 031 | 0.0 | 179.868896 | 0.0 | |
| 032 | 0.0 | 132.696247 | 0.0 | |
| 033 | 0.0 | 135.390288 | 0.0 | |
| 035 | 0.0 | 147.458950 | 0.0 | |
| 036 | 0.0 | 128.887840 | 0.0 | |
| 037 | 0.0 | 147.225241 | 0.0 | |
| 038 | 0.0 | 186.334547 | 0.0 | |
| 039 | 0.0 | 145.273403 | 0.0 | |
| 041 | 0.0 | 139.821081 | 0.0 | |
| 043 | 0.0 | 138.994603 | 0.0 | |
| 044 | 0.0 | 139.646277 | 0.0 | |
| 045 | 0.0 | 182.059329 | 0.0 | |
| 046 | 0.0 | 158.446049 | 0.0 | |
| 047 | 0.0 | 154.805714 | 0.0 | |
| 049 | 0.0 | 198.860705 | 0.0 | |
| 050 | 0.0 | 199.209464 | 0.0 | |

| Building Identifier | Subgrade Enclosures | Substructure Interior | \ |
|---|---|---|---|
| 001 | 9.652903 | 7.521547 | |
| 002 | 6.851955 | 11.871041 | |
| 003 | 11.298572 | 8.277288 | |
| 004 | 4.351465 | 20.070275 | |
| 007 | 9.478642 | 5.575509 | |
| 008 | 4.218921 | 1.817270 | |

| | | |
|---|---|---|
| 009 | 8.902623 | 25.192687 |
| 010 | 9.601245 | 7.744759 |
| 013 | 3.818403 | 9.532825 |
| 014 | 7.722754 | 6.168162 |
| 015 | 9.135529 | 5.601240 |
| 016 | 4.868508 | 9.004152 |
| 019 | 0.000000 | 8.758309 |
| 020 | 4.617006 | 11.946436 |
| 021 | 7.131170 | 8.875410 |
| 022 | 7.959752 | 9.098153 |
| 023 | 6.339651 | 11.209887 |
| 025 | 7.469048 | 3.895085 |
| 026 | 9.448689 | 4.154656 |
| 028 | 0.000000 | 11.506782 |
| 029 | 11.919460 | 8.789598 |
| 031 | 7.509119 | 10.575300 |
| 032 | 5.073992 | 8.309600 |
| 033 | 8.867868 | 13.435344 |
| 035 | 0.000000 | 10.013415 |
| 036 | 4.762839 | 19.086997 |
| 037 | 9.538939 | 12.833857 |
| 038 | 6.039206 | 7.143042 |
| 039 | 9.071017 | 12.485838 |
| 041 | 7.568785 | 12.011677 |
| 043 | 4.540919 | 10.725241 |
| 044 | 6.720435 | 8.275280 |
| 045 | 6.092739 | 10.878686 |
| 046 | 9.489156 | 13.750663 |
| 047 | 6.042229 | 8.345960 |
| 049 | 6.057127 | 5.861907 |
| 050 | 7.221222 | 8.240307 |

| Building Identifier | Substructure Related Activities | Superstructure | \ |
|---|---|---|---|
| 001 | 0.0 | 30.228003 | |
| 002 | 0.0 | 26.271523 | |
| 003 | 0.0 | 23.756286 | |
| 004 | 0.0 | 30.396721 | |
| 007 | 0.0 | 39.906513 | |
| 008 | 0.0 | 39.907474 | |
| 009 | 0.0 | 38.291591 | |
| 010 | 0.0 | 35.370538 | |
| 013 | 0.0 | 35.355314 | |
| 014 | 0.0 | 33.388004 | |
| 015 | 0.0 | 39.370016 | |
| 016 | 0.0 | 40.958564 | |
| 019 | 0.0 | 63.006044 | |
| 020 | 0.0 | 36.597047 | |

| | | |
|---|---|---|
| 021 | 0.0 | 28.734226 |
| 022 | 0.0 | 37.457583 |
| 023 | 0.0 | 36.265538 |
| 025 | 0.0 | 30.389475 |
| 026 | 0.0 | 43.728928 |
| 028 | 0.0 | 35.393414 |
| 029 | 0.0 | 39.408113 |
| 031 | 0.0 | 82.392236 |
| 032 | 0.0 | 46.380703 |
| 033 | 0.0 | 25.469871 |
| 035 | 0.0 | 35.666107 |
| 036 | 0.0 | 49.284461 |
| 037 | 0.0 | 34.035382 |
| 038 | 0.0 | 47.065025 |
| 039 | 0.0 | 37.921434 |
| 041 | 0.0 | 27.740220 |
| 043 | 0.0 | 29.045531 |
| 044 | 0.0 | 33.265489 |
| 045 | 0.0 | 37.265275 |
| 046 | 0.0 | 46.860447 |
| 047 | 0.0 | 31.152827 |
| 049 | 0.0 | 49.899420 |
| 050 | 0.0 | 38.021046 |

| Building Identifier | Water And Gas Mitigation |
|---|---|
| 001 | 0.0 |
| 002 | 0.0 |
| 003 | 0.0 |
| 004 | 0.0 |
| 007 | 0.0 |
| 008 | 0.0 |
| 009 | 0.0 |
| 010 | 0.0 |
| 013 | 0.0 |
| 014 | 0.0 |
| 015 | 0.0 |
| 016 | 0.0 |
| 019 | 0.0 |
| 020 | 0.0 |
| 021 | 0.0 |
| 022 | 0.0 |
| 023 | 0.0 |
| 025 | 0.0 |
| 026 | 0.0 |
| 028 | 0.0 |
| 029 | 0.0 |
| 031 | 0.0 |

```
032                                    0.0
033                                    0.0
035                                    0.0
036                                    0.0
037                                    0.0
038                                    0.0
039                                    0.0
041                                    0.0
043                                    0.0
044                                    0.0
045                                    0.0
046                                    0.0
047                                    0.0
049                                    0.0
050                                    0.0
```

[38]:
```
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() }
```

[39]:
```
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'])
```

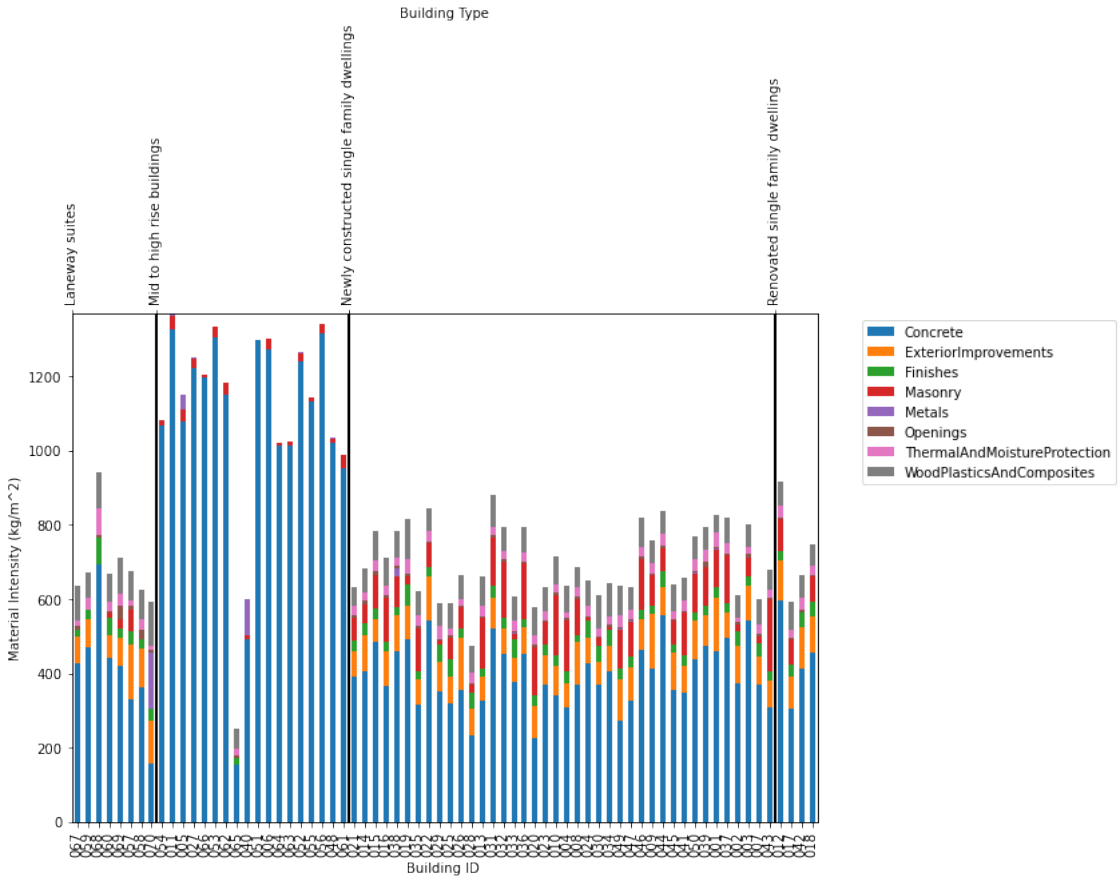
[40]:
```
building_type_map = dict(building_name_conversion[['Building Code','Type']].
 ↪values)

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

[41]:
```
set(df['Building Type'].values)
```

[41]:
```
{'APB', 'EDU', 'INS', 'LNW', 'MIX', 'OFF', 'SMD', 'SMR', 'SND', 'SNR', 'TWN'}
```

[42]:
```
fig, ax = plt.subplots(figsize=(10,7))

cols = toplot.columns[5:]
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()
```




[43]:
```
toplot['Total MI'] = toplot.iloc[:,5:].sum(axis=1)
```

[44]:
```
print('Mean Material Intensity:')
display(toplot.groupby('Building Type').mean().iloc[:,1:].round(2))
print('Std Dev Material Intensity:')
display(toplot.groupby('Building Type').std().iloc[:,1:].round(2))
```

```
Mean Material Intensity:
```

| Building Identifier | Gross Floor Area | Concrete | \ |
|---|---|---|---|
| Building Type | | | |
| Laneway suites | 128.88 | 412.96 | |
| Mid to high rise buildings | 41933.13 | 1070.18 | |
| Newly constructed single family dwellings | 461.18 | 396.71 | |
| Renovated single family dwellings | 277.06 | 442.97 | |

| Building Identifier | ExteriorImprovements | Finishes | \ |
|---|---|---|---|
| Building Type | | | |
| Laneway suites | 81.80 | 35.26 | |
| Mid to high rise buildings | 0.00 | 0.99 | |

| | | |
|---|---|---|
| Newly constructed single family dwellings | 86.16 | 31.17 |
| Renovated single family dwellings | 100.30 | 33.64 |

| Building Identifier | Masonry | Metals | Openings | \ |
|---|---|---|---|---|
| Building Type | | | | |
| Laneway suites | 11.68 | 18.65 | 12.42 | |
| Mid to high rise buildings | 18.83 | 8.57 | 0.39 | |
| Newly constructed single family dwellings | 83.77 | 0.96 | 5.99 | |
| Renovated single family dwellings | 55.31 | 0.74 | 5.84 | |

| Building Identifier | ThermalAndMoistureProtection | \ |
|---|---|---|
| Building Type | | |
| Laneway suites | 28.81 | |
| Mid to high rise buildings | 0.97 | |
| Newly constructed single family dwellings | 25.63 | |
| Renovated single family dwellings | 26.98 | |

| Building Identifier | WoodPlasticsAndComposites | Total MI |
|---|---|---|
| Building Type | | |
| Laneway suites | 89.25 | 690.83 |
| Mid to high rise buildings | 3.02 | 1102.96 |
| Newly constructed single family dwellings | 68.82 | 699.22 |
| Renovated single family dwellings | 64.59 | 730.36 |

Std Dev Material Intensity:

| Building Identifier | Gross Floor Area | Concrete | \ |
|---|---|---|---|
| Building Type | | | |
| Laneway suites | 50.64 | 150.56 | |
| Mid to high rise buildings | 32439.52 | 302.20 | |
| Newly constructed single family dwellings | 168.17 | 82.14 | |
| Renovated single family dwellings | 117.28 | 120.26 | |

| Building Identifier | ExteriorImprovements | Finishes | \ |
|---|---|---|---|
| Building Type | | | |
| Laneway suites | 43.53 | 17.14 | |
| Mid to high rise buildings | 0.00 | 4.22 | |
| Newly constructed single family dwellings | 22.30 | 9.40 | |
| Renovated single family dwellings | 12.94 | 6.38 | |

| Building Identifier | Masonry | Metals | Openings | \ |
|---|---|---|---|---|
| Building Type | | | | |
| Laneway suites | 20.51 | 52.54 | 11.58 | |
| Mid to high rise buildings | 11.42 | 23.39 | 1.66 | |
| Newly constructed single family dwellings | 49.26 | 3.35 | 2.21 | |
| Renovated single family dwellings | 37.88 | 0.86 | 1.43 | |

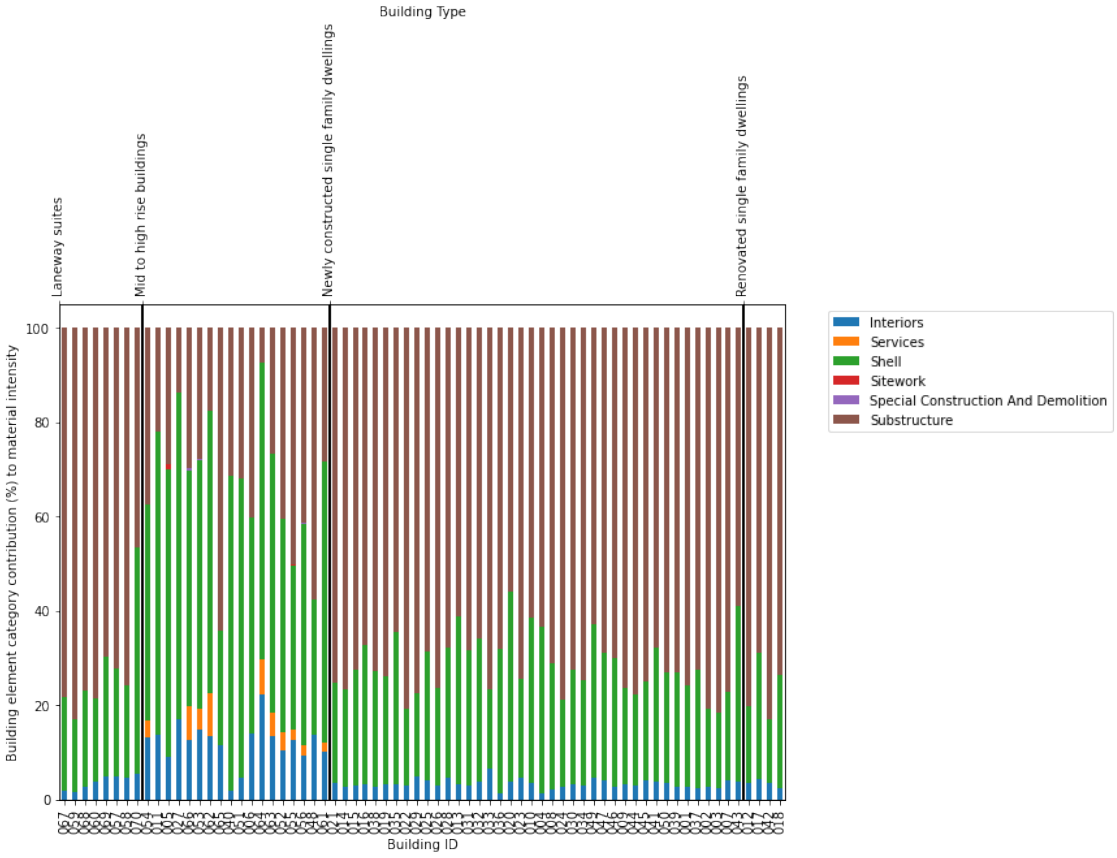
| Building Identifier | ThermalAndMoistureProtection | \ |
|---|---|---|
| Building Type | | |

```
Laneway suites                                                    19.63
Mid to high rise buildings                                         4.13
Newly constructed single family dwellings                          6.14
Renovated single family dwellings                                  5.44

Building Identifier                        WoodPlasticsAndComposites  Total MI
Building Type
Laneway suites                                                 17.69    107.85
Mid to high rise buildings                                     12.82    280.73
Newly constructed single family dwellings                      11.58     95.96
Renovated single family dwellings                               6.55    140.02
```

[45]:
```
df_mi = df[kilogram_columns].div(df['Gross Floor Area'],axis=0)
```

[46]:
```
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[5:]
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()
```



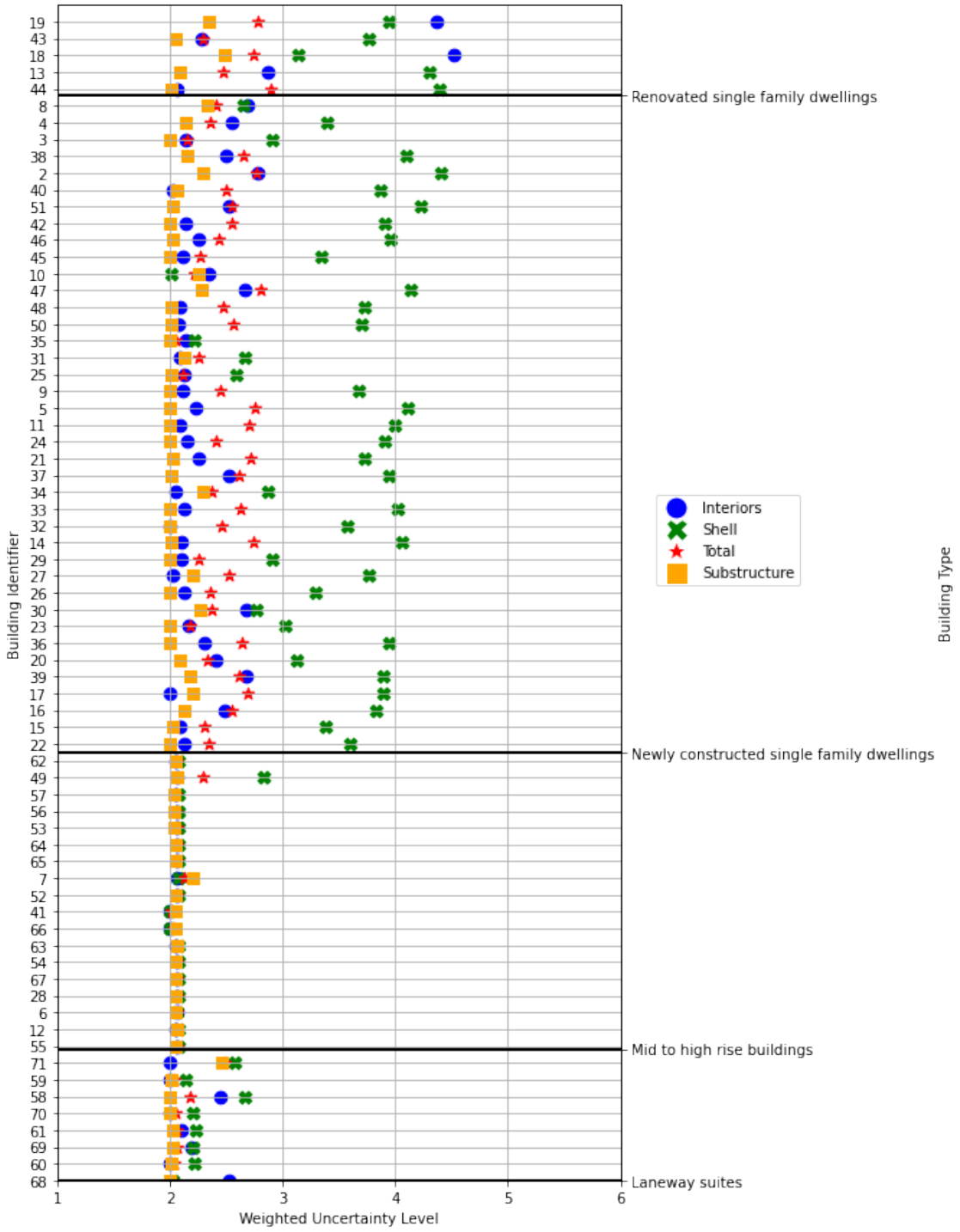

[47]:
```
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0]] + '/' + re.split('[_\.\␣
↪]',x)[-1]
toplot = df_mi[kilogram_columns].groupby(f,axis=1).sum()
```

[48]:
```
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(1,6):
    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'] = toplot_out['index'].astype('int') + 1
toplot_out['index'] = toplot_out['index'].astype('str')
```

[49]:
```
# 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')
```

[50]:
```
from matplotlib.lines import Line2D
fig, ax = plt.subplots(figsize=(7,15))
ax.set_xlim(1,6)
ax.set_ylim(0,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-1.5 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)
```




[51]:
```
toplot_out
```

[51]:

| | index | Building Type | Interiors | Services | \ |
|---|---|---|---|---|---|
| 18 | 68 | Laneway suites | 2.520976 | 0.0 | |

```
17    60                                Laneway suites   2.000000       0.0
16    69                                Laneway suites   2.190950       0.0
15    61                                Laneway suites   2.106514       0.0
11    70                                Laneway suites   2.005075       0.0
..   …                                             …       …       …
34    44  Newly constructed single family dwellings   2.065774       0.0
28    13           Renovated single family dwellings   2.868511       0.0
66    18           Renovated single family dwellings   4.523878       0.0
67    43           Renovated single family dwellings   2.275307       0.0
68    19           Renovated single family dwellings   4.371953       0.0

       Shell  Sitework  Special Construction And Demolition  Substructure  \
18  2.025651       0.0                                  0.0      2.000000
17  2.222478       0.0                                  0.0      2.009786
16  2.206190       0.0                                  0.0      2.023037
15  2.229146       0.0                                  0.0      2.024653
11  2.200763       0.0                                  0.0      2.000000
..       …       …                                    …           …
34  4.396133       0.0                                  0.0      2.005594
28  4.306551       0.0                                  0.0      2.082720
66  3.139931       0.0                                  0.0      2.480406
67  3.763229       0.0                                  0.0      2.056058
68  3.946027       0.0                                  0.0      2.342662

       Total
18  2.015289
17  2.042591
16  2.064759
15  2.063625
11  2.051110
..       …
34  2.900427
28  2.475825
66  2.744405
67  2.294809
68  2.777552

[70 rows x 9 columns]
```

# 6 Additional Characteristics

## 6.1 1. Count number of floors in a given building based on position relative to the ground.

[52]:
```
from collections import Counter
import re
import eeweather
BUILDING_ID = '043' #As an example, select building 043
building_data = df.loc[BUILDING_ID]
```

[53]:
```
seen = set()
c = Counter()
for k,v in building_data.items():
    floor = k.split('_')[0]
    if floor in seen or v!=v or 'kg' not in k:
        continue
    seen.add(floor)
for x in seen:
    parts = re.split('([A-Z])',x)
    parts = [p for p in parts if p!='']
    parts = [int(p) if p.isdigit() else p for p in parts]
    if 'B' in parts:
        c.update(['Basement'])
    elif 'R' in parts:
        c.update(['Roof'])
    elif 0 in parts:
        c.update(['Ground'])
    else:
        c.update(['Above Ground'])
print(f'Floors relative to ground for building {BUILDING_ID}:')
for k,v in c.items():
    print(f'{k}: {v} floor(s)')
```

```
Floors relative to ground for building 043:
Ground: 1 floor(s)
Above Ground: 2 floor(s)
Basement: 1 floor(s)
Roof: 1 floor(s)
```

## 6.2 2. Get climate conditions for a given building

This code retrieves local climate zones for a given building.

[54]:
```
from geopy.geocoders import Nominatim
locator = Nominatim(user_agent="ConstructionDataset")
name_map = {
    'TOR':'Toronto',
```

```
    'WIN':'Winnipeg',
    'NEW':'New York',
    'RIC':'Richmond',
    'MIS':'Mississuaga'
}
location = locator.geocode(f'{name_map[building_data.City]}, {building_data.
 ↪Country}')
```

[55]:
```
ranked_stations = eeweather.rank_stations(location.latitude,location.longitude)
ranked_stations = ranked_stations[~ranked_stations.iecc_climate_zone.isnull()]
station, warnings = eeweather.select_station(ranked_stations)
```

[56]:
```
print(f'Climate zones for building {BUILDING_ID}:')
for k,v in station.climate_zones.items():
    if v is None:
        continue
    print(f'{k}: {v}')
```

```
Climate zones for building 043:
iecc_climate_zone: 5
iecc_moisture_regime: A
ba_climate_zone: Cold
```

[ ]:
```

```