Sample

October 6, 2021

```python
[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.

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

```python
[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')]
```

```python
[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')
```

```python
[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)
```

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

```python
[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':'OCF',
         'Foundation Walls':'OFW',
         'Spread Footings':'OSF',
         'Column Piers':'OCP',
         'Columns Supporting Floors':'CSF',
         'Floor Girders and Beams':'FGB',
         'Floor Trusses':'OFT',
         'Floor Joists':'OFJ',
         '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.

```
[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)');
```

Histogram of total building material mass
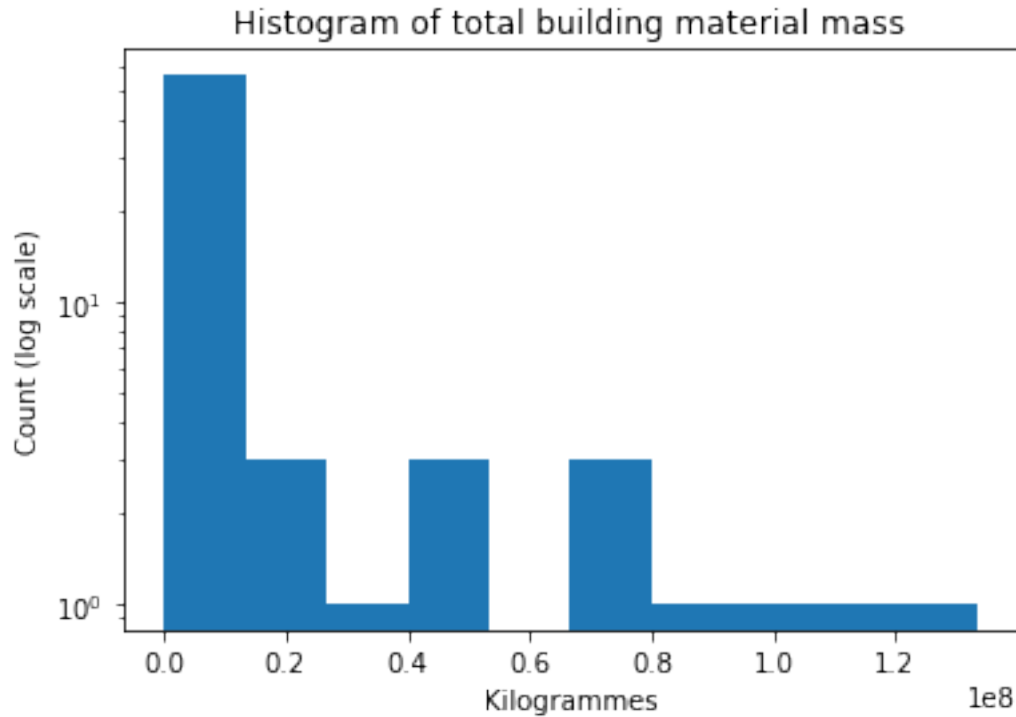
3 2. Investigate a specific material

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
```

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```
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]:
```python
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');
```

Average Material Intensity of concrete used per floor

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
```

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```
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 $> 1\%$

```python
[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();
```

Percentage of total concrete used in each building element category
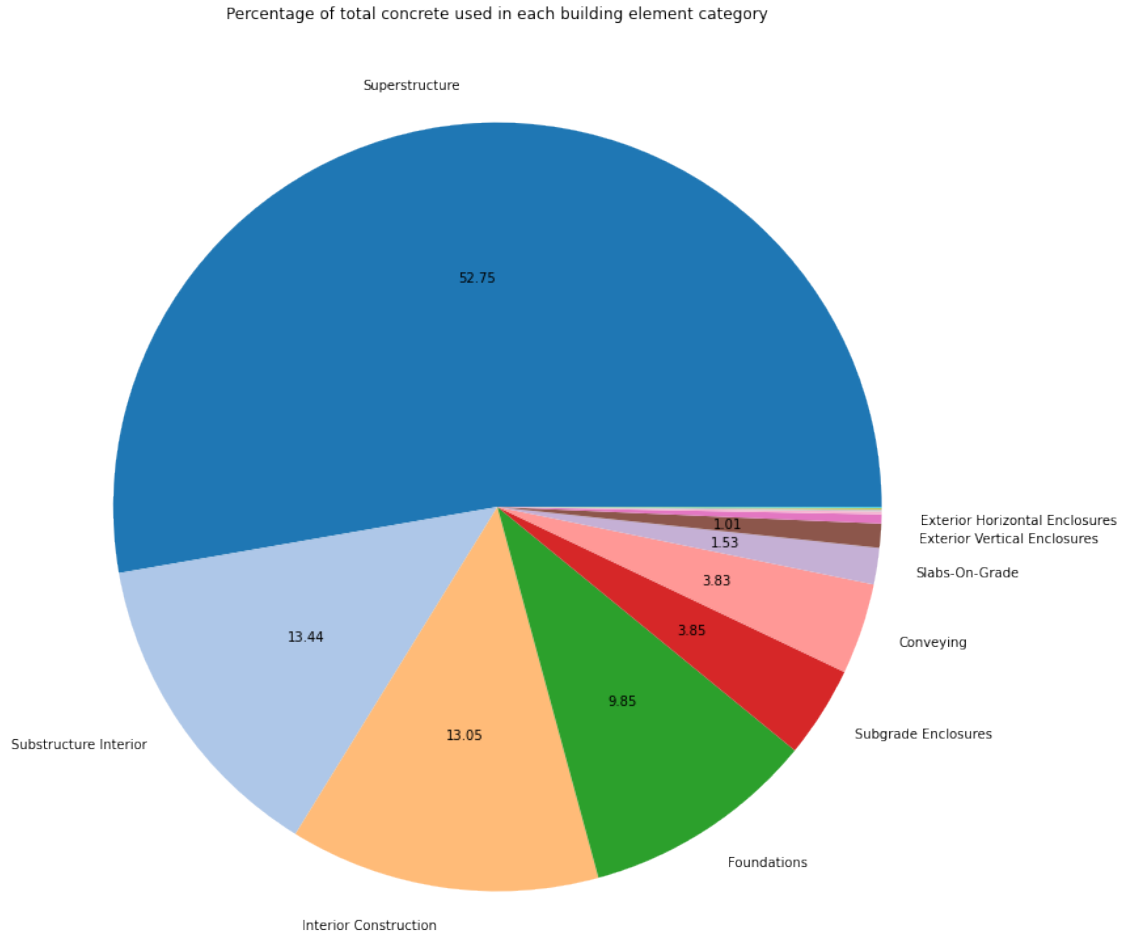
3.2 Pie version B: external legend with slice labels

```
[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: \
```

```python
        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')
```
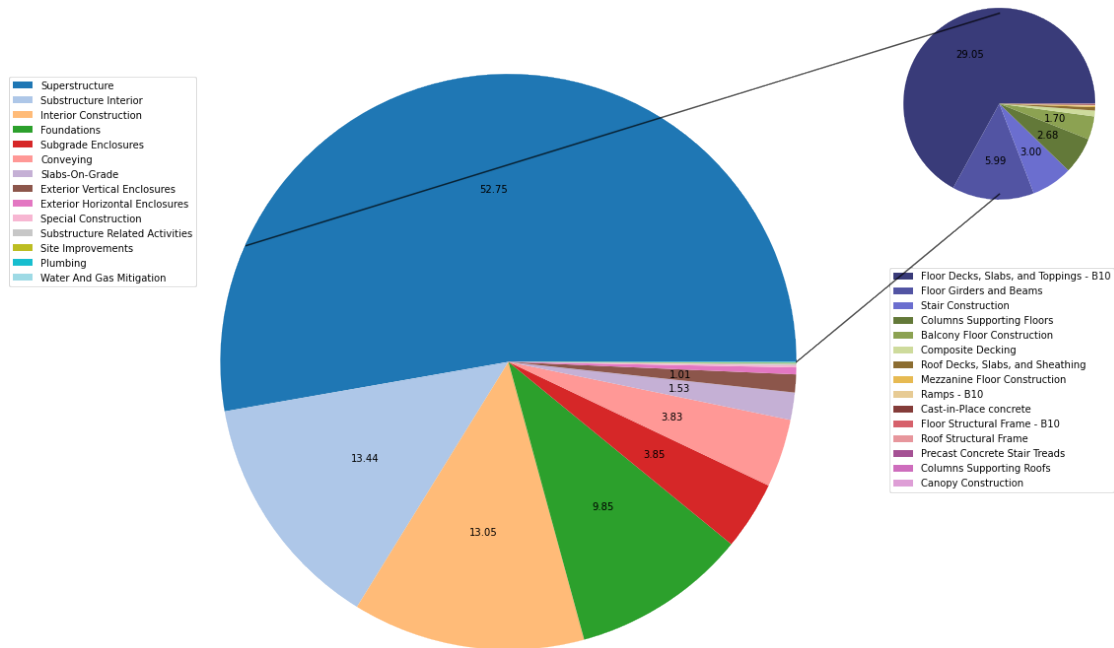
We can produce a pie chart for a single building, also.

```
[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)]
```

11

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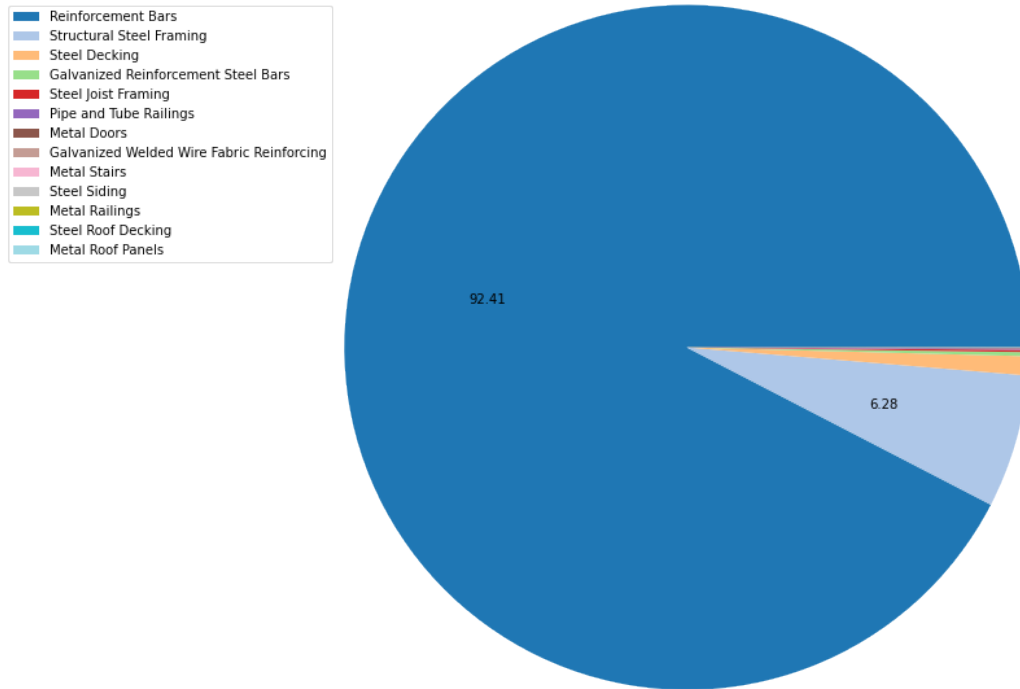
```
[24]: def my_autopct(pct):
          return ('%.2f' % (pct)) if pct > 1 else ''
      to_plot = steel_df.sum().sort_values(ascending=False)
      to_plot.plot.
      →pie(figsize=(12,12),colormap='tab20',autopct=my_autopct,labeldistance=None)
      plt.legend(loc='center left',bbox_to_anchor=(-0.30,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

Types of steel use in all buildings in terms of MasterFormat categories

Legend:
- Reinforcement Bars
- Structural Steel Framing
- Steel Decking
- Galvanized Reinforcement Steel Bars
- Steel Joist Framing
- Pipe and Tube Railings
- Metal Doors
- Galvanized Welded Wire Fabric Reinforcing
- Metal Stairs
- Steel Siding
- Metal Railings
- Steel Roof Decking
- Metal Roof Panels

92.41

6.28

[25]:
```python
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]:
```python
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')
```

Types of steel use in building 48 in terms of MasterFormat categories
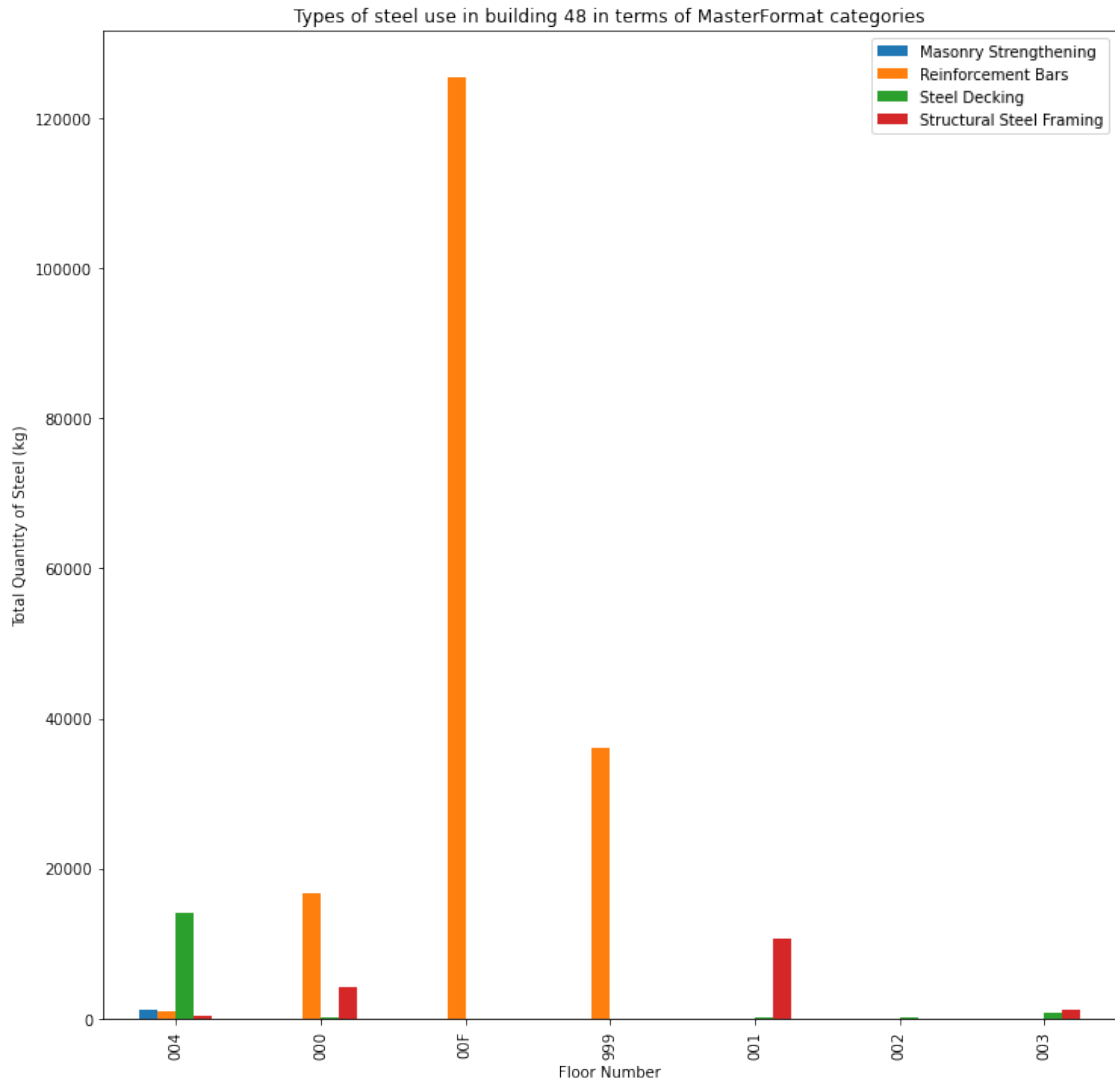
We can also calculate the average for each Level 3 MasterFormat code by year of construction:

```
[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
```

Building Identifier		
Construction Date		
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	Cast-in-Place Concrete/002	Cast-in-Place Concrete/003 \
Construction Date		
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	Cast-in-Place Concrete/004	Cast-in-Place Concrete/005 \
Construction Date		
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 322 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');
```

Average amount of concrete used in a building by building type
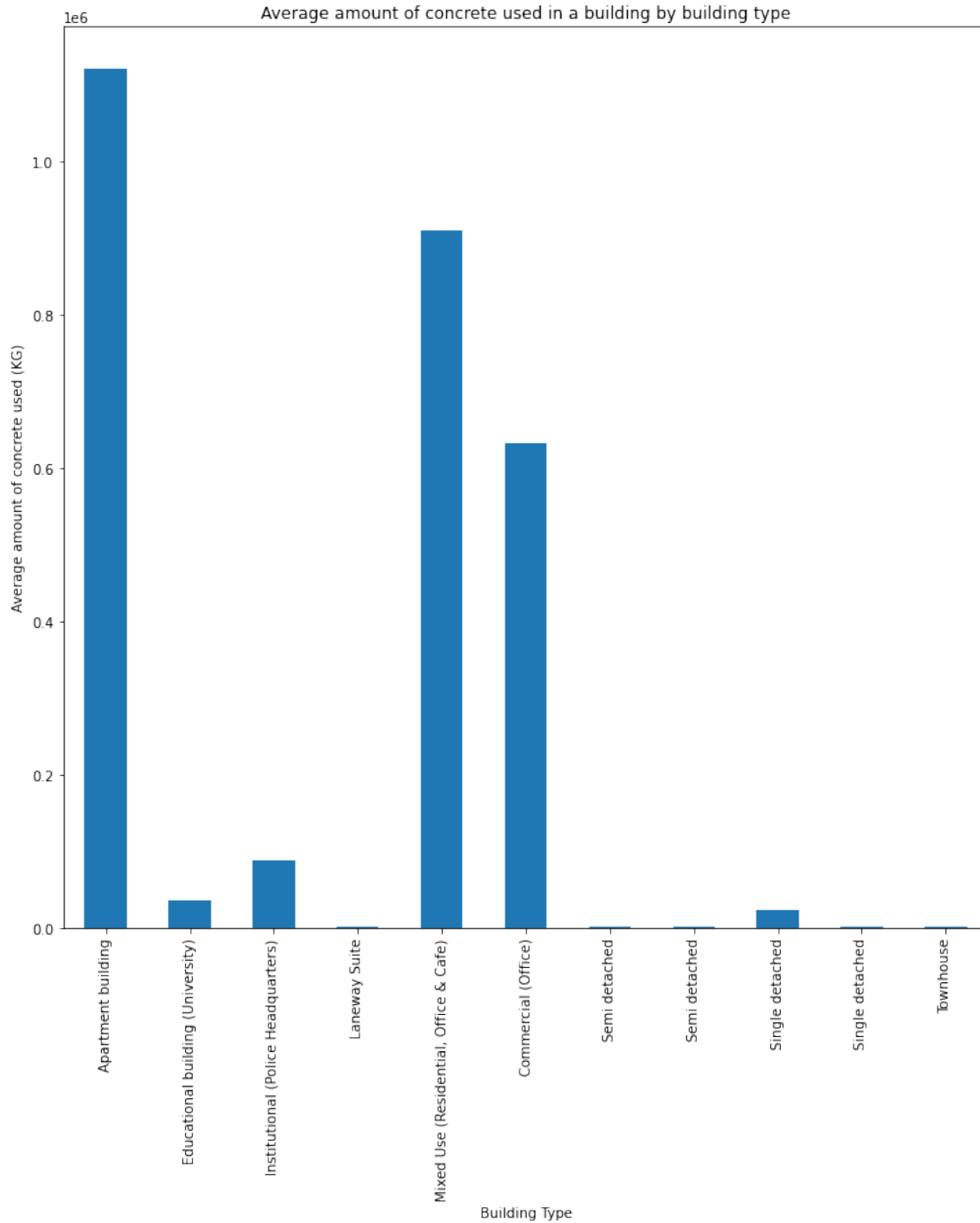
4 3. Uncertainty by Building Type

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': 1601}),
       '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 Identifier                      Gross Floor Area   Interiors/2  \
      Building Type
      Apartment building                              39160.26    5624203.35
      Educational building (University)                7901.00     480382.15
      Institutional (Police Headquarters)             21934.00    1295281.75
      Laneway Suite                                     128.88          0.00
```

```
Mixed Use (Residential, Office & Cafe)          80760.42  12716484.57
Commercial (Office)                             52643.67   9898215.44
Semi detached                                     248.84         0.00
Semi detached                                     199.93         0.00
Single detached                                   478.40         0.00
Single detached                                   302.76         0.00
Townhouse                                        3566.00         0.00

Building Identifier                     Interiors/3  Interiors/4  Services/2  \
Building Type
Apartment building                             0.00    171337.00   1529274.0
Educational building (University)           3096.66     14080.27         0.0
Institutional (Police Headquarters)            0.00     40860.46         0.0
Laneway Suite                                  0.00         0.00         0.0
Mixed Use (Residential, Office & Cafe)         0.00    370412.46   7268736.0
Commercial (Office)                            0.00    285637.96         0.0
Semi detached                                  0.00         0.00         0.0
Semi detached                                  0.00         0.00         0.0
Single detached                                0.00         0.00         0.0
Single detached                               68.77         0.00         0.0
Townhouse                                      0.00         0.00         0.0

Building Identifier                      Services/4       Shell/2       Shell/3  \
Building Type
Apartment building                        50074.69  20886862.84          0.00
Educational building (University)             0.00   1520252.59     834695.64
Institutional (Police Headquarters)           0.00  17371405.92          0.00
Laneway Suite                                 0.00         0.00          0.00
Mixed Use (Residential, Office & Cafe)   237801.46  51743951.21          0.00
Commercial (Office)                           0.00  43308969.36          0.00
Semi detached                                 0.00      1866.95          5.41
Semi detached                                 0.00         0.00         40.11
Single detached                               0.00      1549.49         22.18
Single detached                               0.00      2504.95          6.65
Townhouse                                     0.00         0.00          0.00

Building Identifier                        Shell/4  Shell/5   Sitework/2  \
Building Type
Apartment building                       761128.06     0.00      14493.0
Educational building (University)          7713.03     0.00          0.0
Institutional (Police Headquarters)      656655.11     0.00          0.0
Laneway Suite                                 0.00     0.00          0.0
Mixed Use (Residential, Office & Cafe)  1909970.03     0.00          0.0
Commercial (Office)                     1621345.80     0.00      89288.0
Semi detached                                 0.00     0.00          0.0
Semi detached                                 0.00     0.00          0.0
Single detached                               0.00     0.93          0.0
```

```
Single detached                                    0.00      0.00          0.0
Townhouse                                          0.00      0.00          0.0


Building Identifier                     Sitework/4   \
Building Type
Apartment building                      474.04
Educational building (University)         0.00
Institutional (Police Headquarters)       0.00
Laneway Suite                             0.00
Mixed Use (Residential, Office & Cafe)    0.00
Commercial (Office)                     3016.86
Semi detached                             0.00
Semi detached                             0.00
Single detached                           0.00
Single detached                           0.00
Townhouse                                 0.00


Building Identifier                     Special Construction And Demolition/2   \
Building Type
Apartment building                                                     37698.0
Educational building (University)                                          0.0
Institutional (Police Headquarters)                                        0.0
Laneway Suite                                                              0.0
Mixed Use (Residential, Office & Cafe)                                249760.0
Commercial (Office)                                                        0.0
Semi detached                                                             0.0
Semi detached                                                             0.0
Single detached                                                           0.0
Single detached                                                           0.0
Townhouse                                                                 0.0


Building Identifier                     Special Construction And Demolition/4   \
Building Type
Apartment building                                                      339.88
Educational building (University)                                         0.00
Institutional (Police Headquarters)                                       0.00
Laneway Suite                                                             0.00
Mixed Use (Residential, Office & Cafe)                                  9000.47
Commercial (Office)                                                       0.00
Semi detached                                                             0.00
Semi detached                                                             0.00
Single detached                                                           0.00
Single detached                                                           0.00
Townhouse                                                                 0.00


Building Identifier                     Substructure/2   Substructure/3   \
Building Type
```

Apartment building	15661850.24	109212.00
Educational building (University)	2793438.68	0.00
Institutional (Police Headquarters)	8890567.75	0.00
Laneway Suite	48858.34	2104.66
Mixed Use (Residential, Office & Cafe)	22801051.57	0.00
Commercial (Office)	12411535.27	0.00
Semi detached	97751.05	7.78
Semi detached	110261.75	8921.68
Single detached	181911.50	5413.20
Single detached	93196.84	19429.34
Townhouse	534318.99	0.00

Building Identifier	Substructure/4	Substructure/5
Building Type		
Apartment building	365922.73	0.00
Educational building (University)	91853.12	0.00
Institutional (Police Headquarters)	239579.15	0.00
Laneway Suite	0.00	0.65
Mixed Use (Residential, Office & Cafe)	645320.97	0.00
Commercial (Office)	354767.84	0.00
Semi detached	0.00	6.93
Semi detached	0.00	0.00
Single detached	0.00	38.46
Single detached	0.00	0.00
Townhouse	14428.09	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 (%)

	2	3	4	5
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                0.96  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`:

```python
[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)
```

```python
[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
```

24

```
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  \
```

26

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
```

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

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

[42]:
```python
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()
```
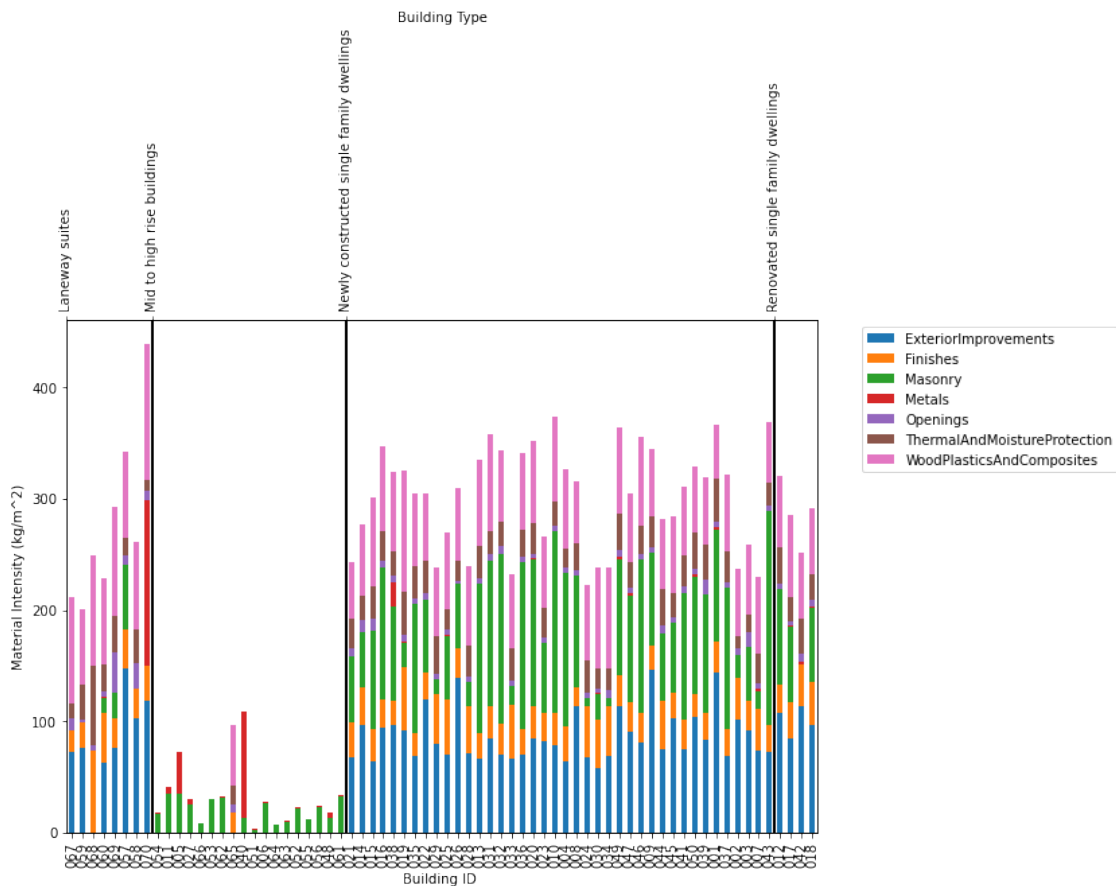


```
[43]: toplot['Total MI'] = toplot.iloc[:,6:].sum(axis=1)
```

```
[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

33

```
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    277.86
Mid to high rise buildings                                      3.02     32.78
Newly constructed single family dwellings                     68.82    302.51
Renovated single family dwellings                             64.59    287.39

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     79.65
Mid to high rise buildings                                           12.82     30.02
Newly constructed single family dwellings                            11.58     46.39
Renovated single family dwellings                                     6.55     28.36
```

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

```python
[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[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()
```
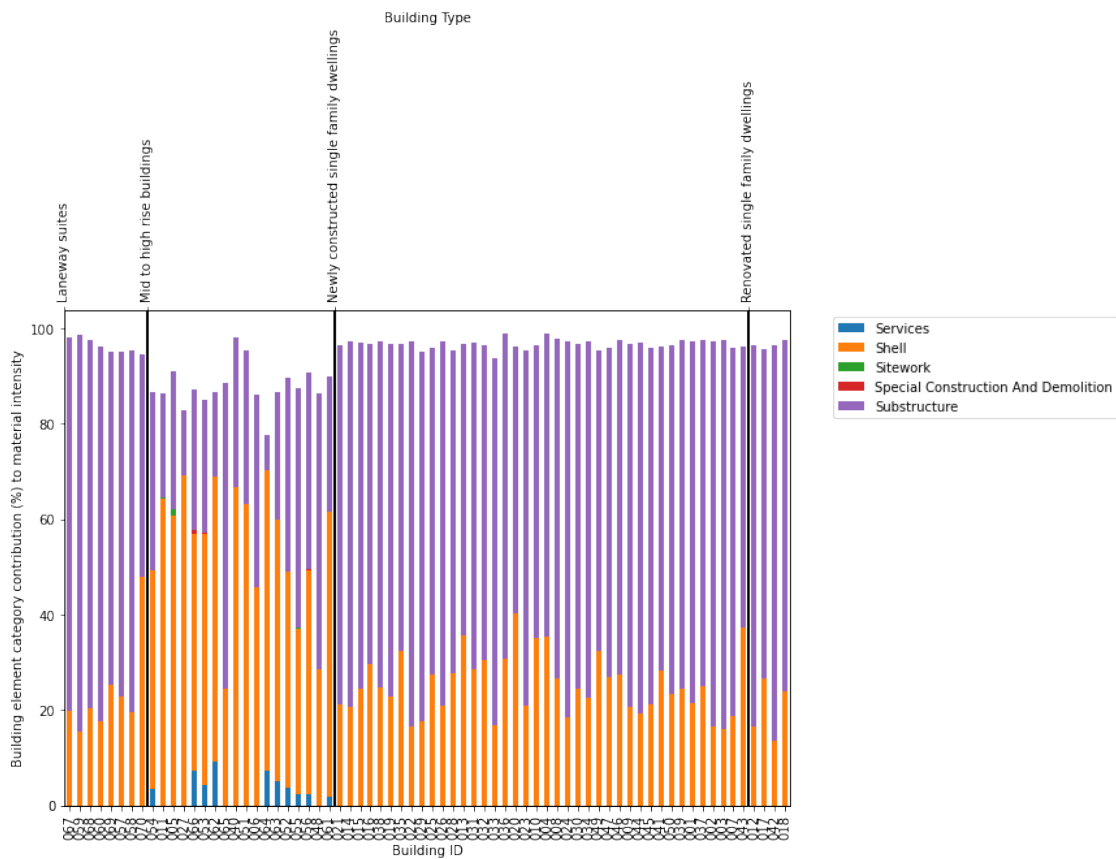

[47]:
```
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0]] + '/' + re.split('[_\.\ ␣
 ↪]',x)[-1]
toplot = df_mi[kilogram_columns].groupby(f,axis=1).sum()
```

[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(1,5)
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])
```

```python
# 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)
```
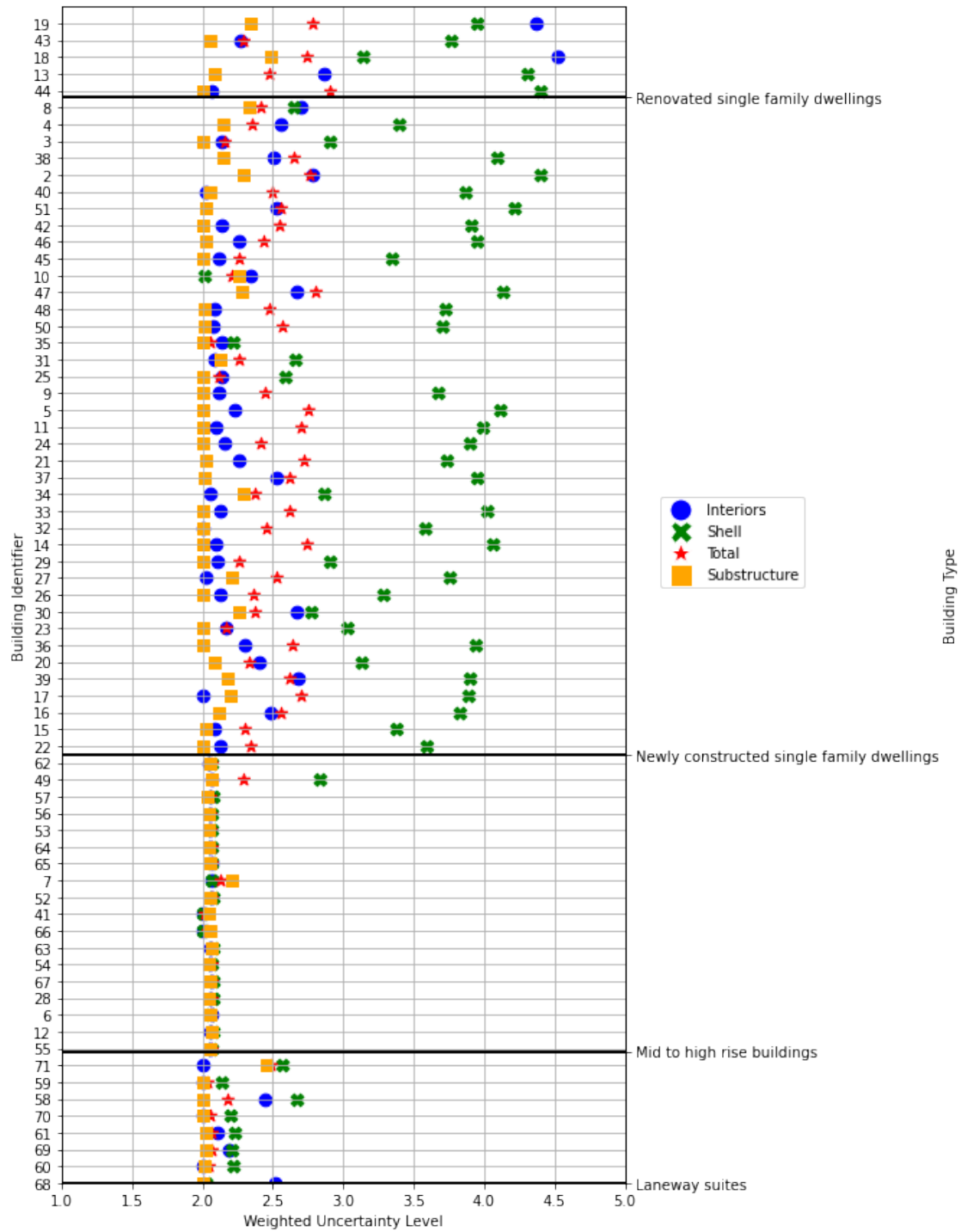
[51]: `toplot_out`

[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
```

[ ]: