Sample

September 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()}
```

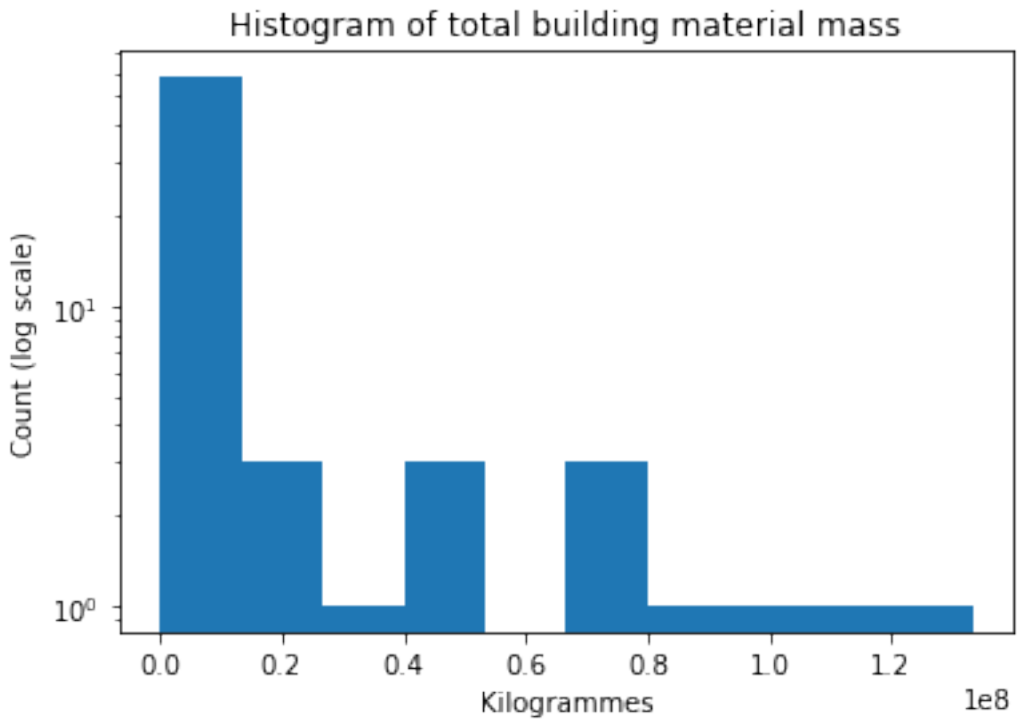
[8]:
```
name_map = {k.Code:k.Category for _,k in name_conversion.iterrows()}
```

[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',
    'Floor Trusses':'FTS',
    '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
```

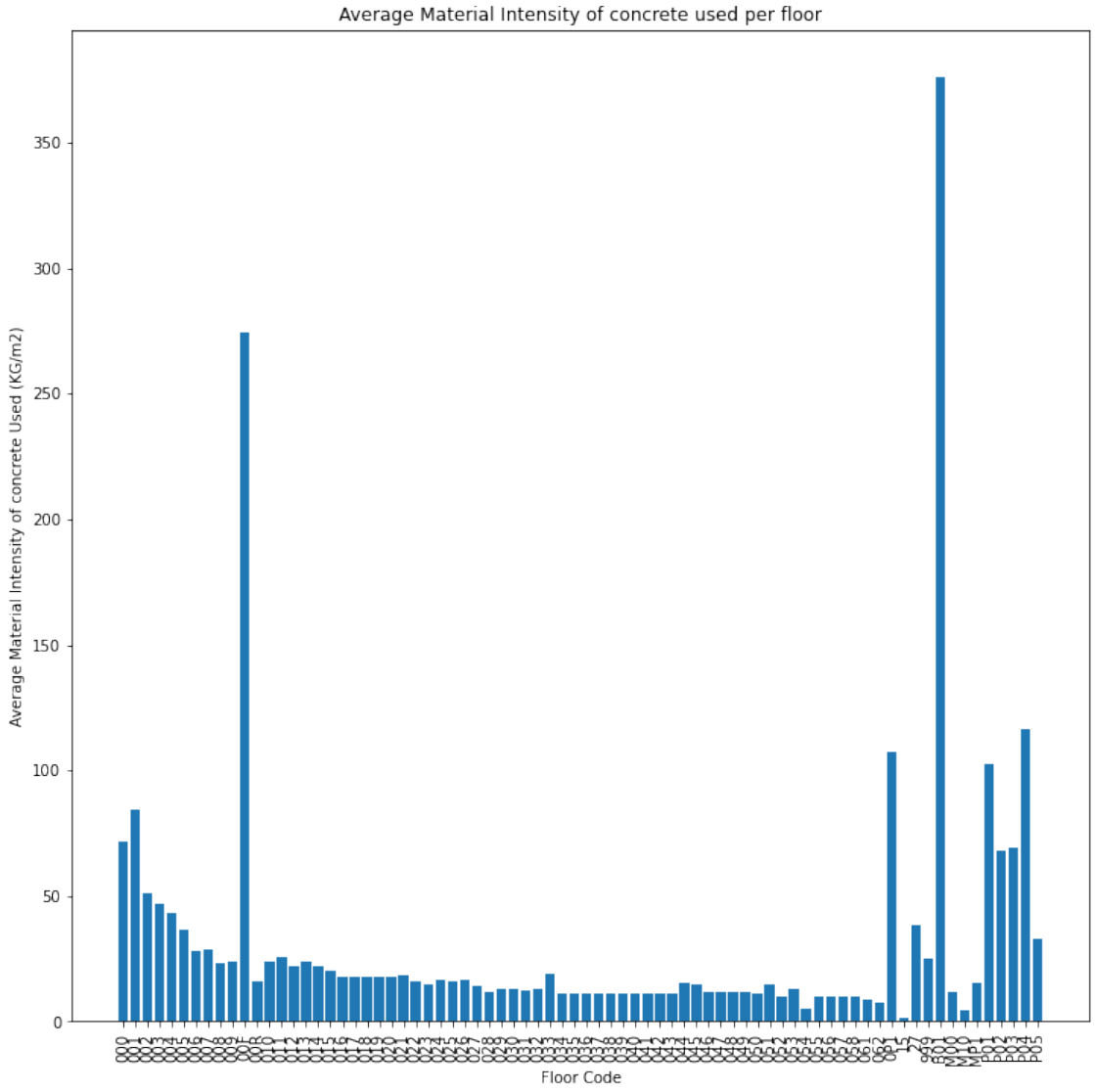
[13]:
```
Building Identifier Country City Quality / Stage of Data  Construction Date  \
001                       CA  TOR                   00IFC                2021
002                       CA  TOR                   00IFC                2021
003                       CA  TOR                   00IFC                2021
004                       CA  TOR                   00IFC                2021
005                       CA  TOR                   00IFC                2011
..                       ...  ...                    ...                 ...
068                       CA  TOR                   00IFT                2020
069                       CA  TOR                   00IFC                2019
```

```
070                      CA  TOR                   0IFBP              2021
071                      CA  TOR                   00IFC              2020
072                      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
..                           …               …          …
068                          MIX          95769.00  1.566786e+07
069                          LNW            131.00  2.657254e+04
070                          LNW             71.00  2.721844e+04
071                          LNW             98.00  2.846246e+04
072                          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
..                                 …            …
068                        3484448.795    1.395514e+06
069                              0.000    2.924485e+04
070                              0.000    2.206696e+04
071                              0.000    1.264324e+04
072                              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
..                                     …                        …
068                           1.368861e+07                       0.0
069                           0.000000e+00                       0.0
070                           0.000000e+00                       0.0
071                           0.000000e+00                       0.0
072                           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
..                                                 …             …
068                                                0.0    5.737703e+07
069                                                0.0    0.000000e+00
070                                                0.0    0.000000e+00
071                                                0.0    0.000000e+00
072                                                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
..                                               …
068                                         71331.23
069                                             0.00
070                                             0.00
071                                             0.00
072                                             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
..                                               …                      …
068                                              0.0           1.463901e+07
069                                              0.0           0.000000e+00
070                                              0.0           0.000000e+00
071                                              0.0           0.000000e+00
072                                              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
..                           …         …                     …
068                  8273703.915       0.0            711760.625
069                        0.000       0.0                 0.000
070                        0.000       0.0                 0.000
071                        0.000       0.0                 0.000
072                        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
..                                    …
068                                0.0000
069                                0.0000
070                                0.0000
071                                0.0000
072                                0.0000

[72 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()
```

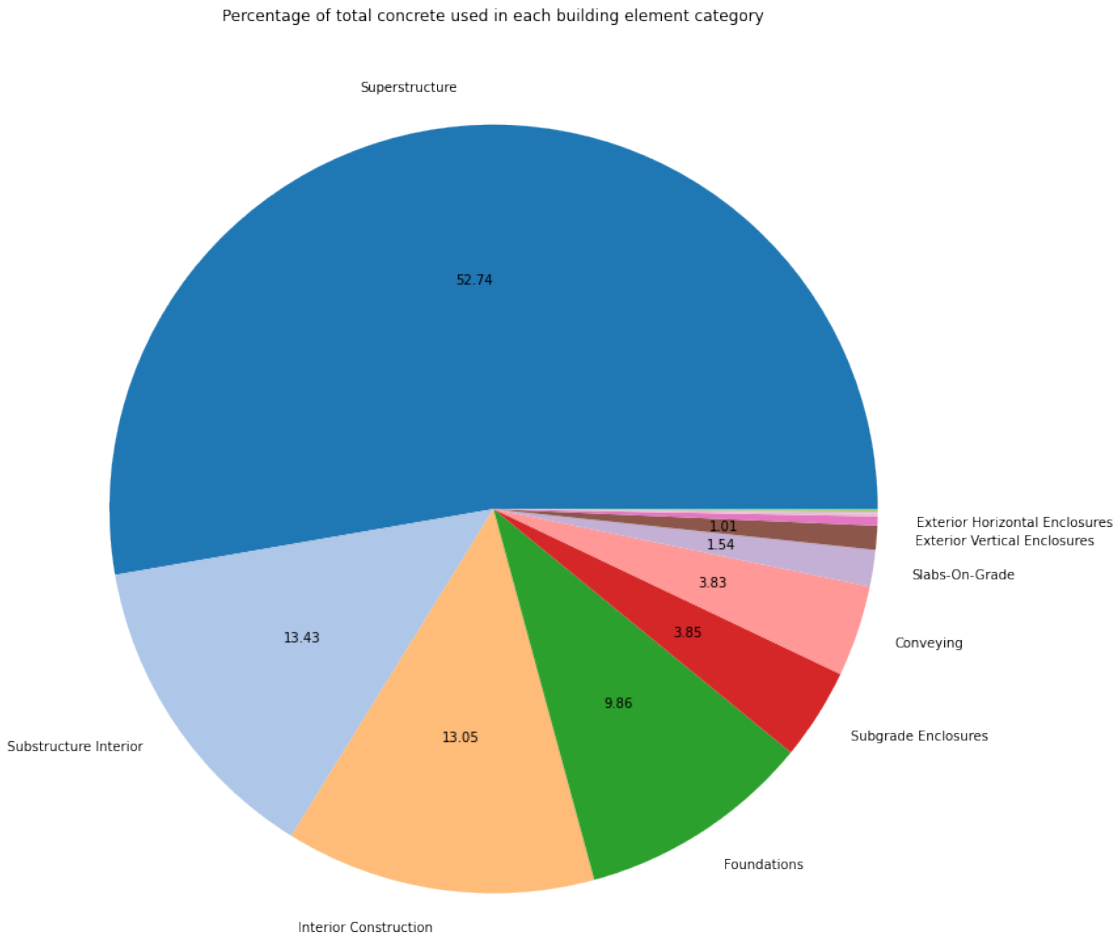
[16]:
```
concrete_df.mean().sort_values(ascending=False)
```

[16]:
```
Building Identifier
Superstructure                  6.654056e+06
Substructure Interior           1.694672e+06
Interior Construction           1.646459e+06
```

```
Foundations                          1.243325e+06
Subgrade Enclosures                  4.858838e+05
Conveying                            4.832128e+05
Slabs-On-Grade                       1.938807e+05
Exterior Vertical Enclosures         1.270600e+05
Exterior Horizontal Enclosures       4.890347e+04
Special Construction                 1.500812e+04
Substructure Related Activities      1.174729e+04
Site Improvements                    5.509040e+03
Plumbing                             5.042747e+03
Water And Gas Mitigation             1.185942e+03
dtype: float64
```

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

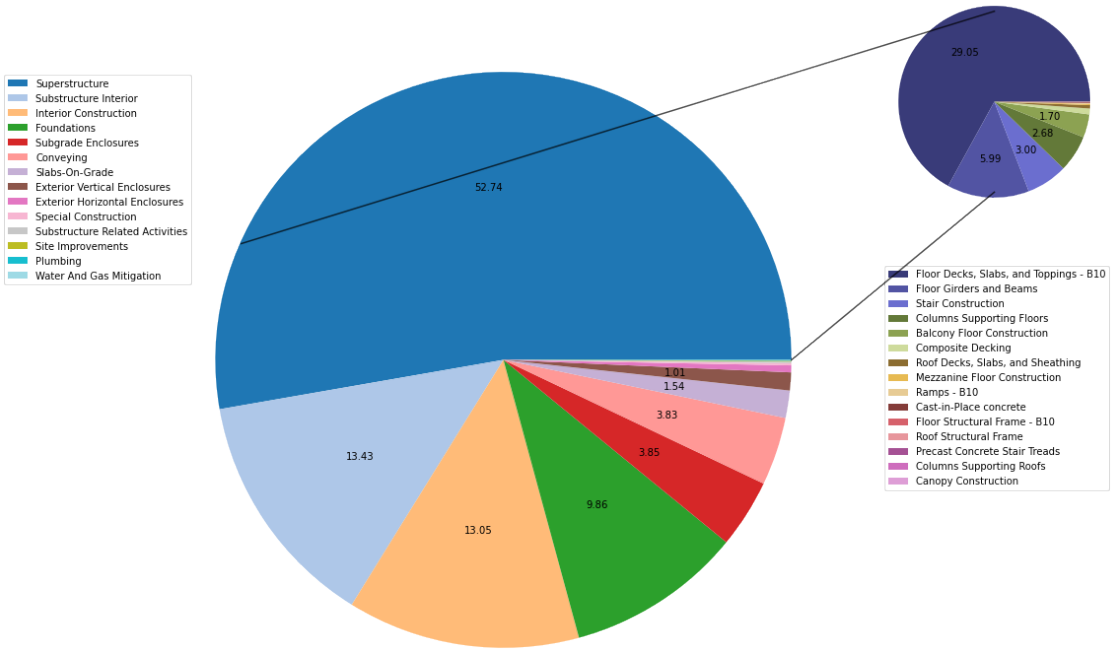
[17]:
```
def my_autopct(pct):
    return ('%.2f' % pct) if pct > 1 else ''
to_plot = concrete_df.mean().sort_values(ascending=False)
to_plot.plot.pie(figsize=(12,12),colormap='tab20',autopct=my_autopct,labels=[k␣
 ↪if v > 35000 else '' for k,v in to_plot.items()])
plt.ylabel('')
plt.title('Percentage 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)]
```

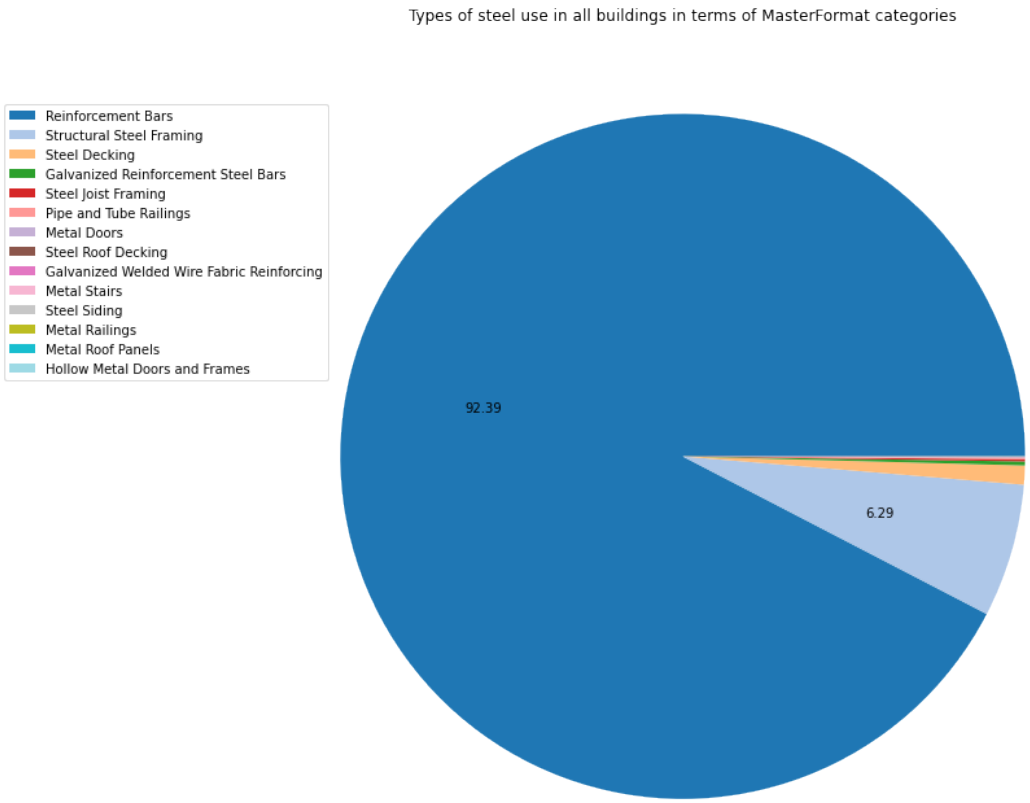
[21]:
```
columns_to_keep = []
for column in df.columns:
    if 'kg' in column:
        code = re.split('_',column)[2]
        for k,c in steel_codes.values:
            if c in code:
                columns_to_keep.append(column)
```

[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()
```

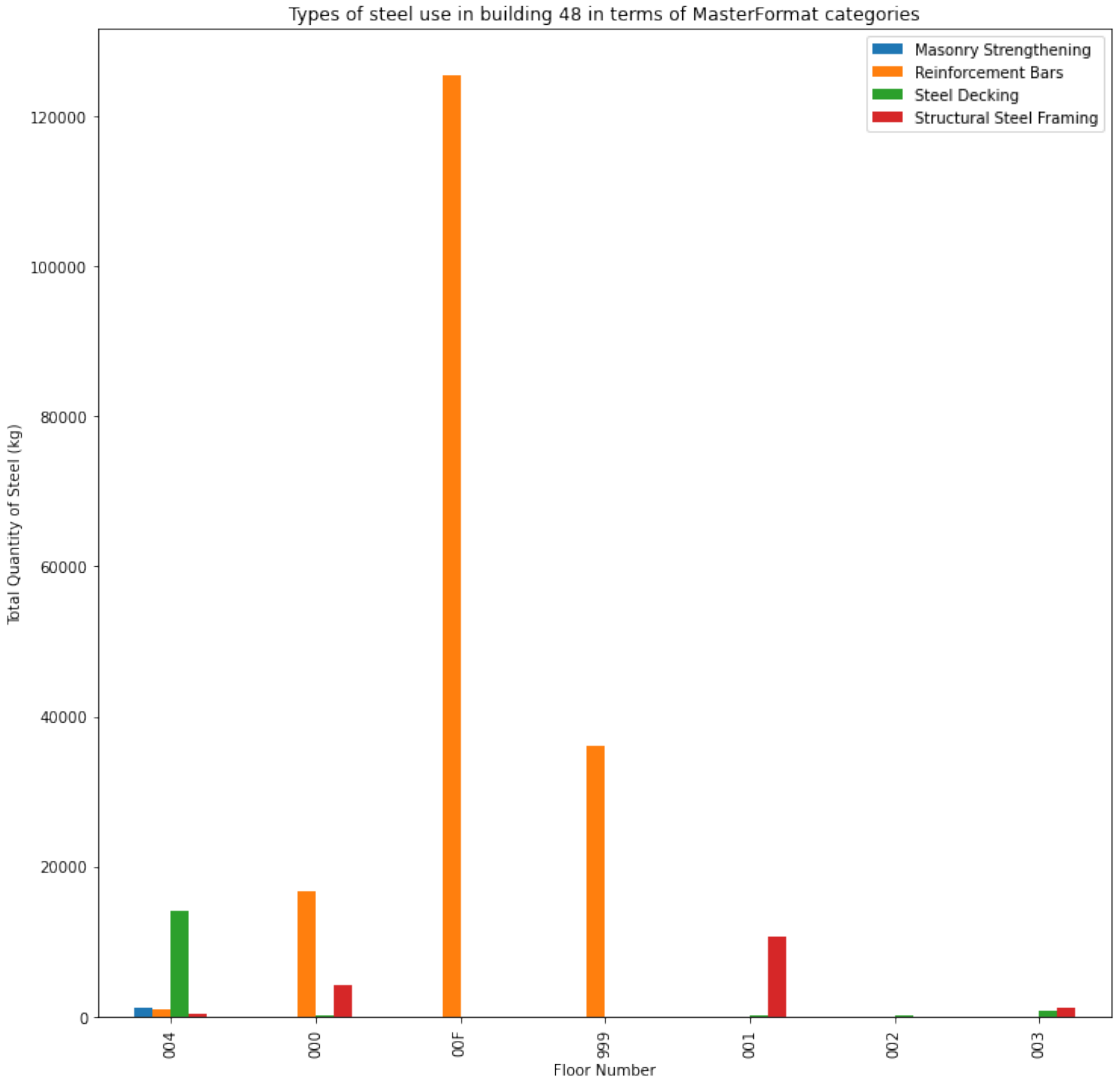
[23]:
```
036    1
069    1
068    1
023    1
035    1
      ..
048    4
050    4
051    4
049    4
061    5
Length: 72, dtype: int64
```

[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	26043.854000	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 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 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 …	355867.2	0.000000
2019 …	0.0	47353.684083
2020 …	34108.8	98902.934000
2021 …	0.0	156066.475284
2025 …	847704.0	0.000000

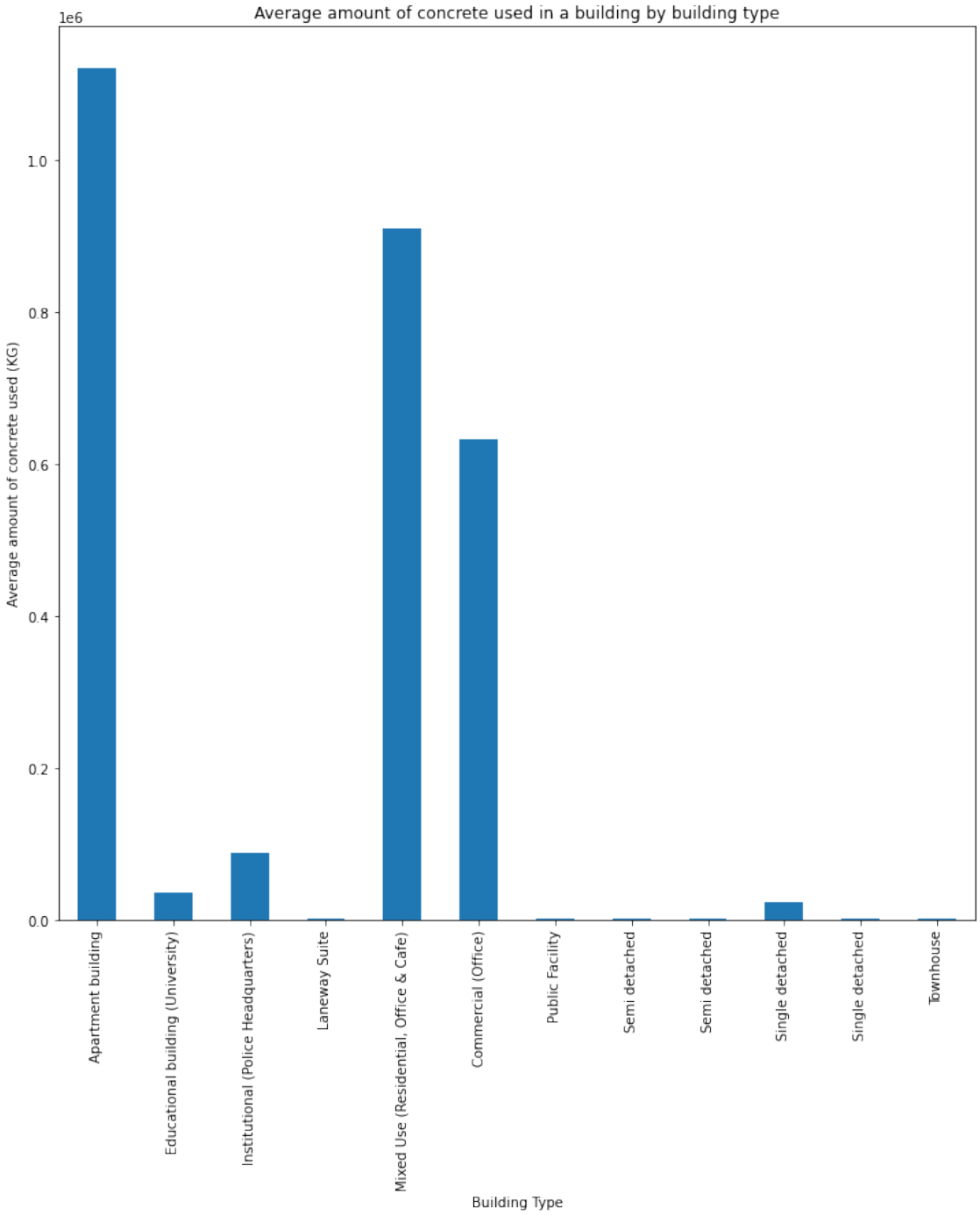
Building Identifier	Structural Concrete/M00	Structural Concrete/M10 \
Construction Date		
1913	0.0	0.0
1917	0.0	0.0
1969	0.0	0.0
1988	0.0	0.0
2007	0.0	0.0
2009	0.0	0.0
2011	0.0	0.0
2016	141136.0	0.0
2017	0.0	0.0
2018	380294.4	0.0
2019	0.0	0.0
2020	65894.4	0.0
2021	0.0	0.0
2025	0.0	391968.0

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	1739889.6
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                              1443475.2                1102766.4
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                              1637313.6                      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');
```



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}),
 'PUF': Counter({'2': 30, '4': 4}),
 '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
Public Facility	62.00	18518.82
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 Building Type	Interiors/3	Interiors/4	Services/2	\
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	
Public Facility	0.00	0.00	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 Building Type	Services/4	Shell/2	Shell/3	\
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	
Public Facility	0.00	0.00	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 Building Type	Shell/4	Shell/5	Sitework/2	\
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
Public Facility	0.00	0.00	0.0
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
Public Facility	0.00
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
Public Facility	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
Public Facility	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
Public Facility                              66060.00            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
Public Facility                               1990.25            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 (%)

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() }
```

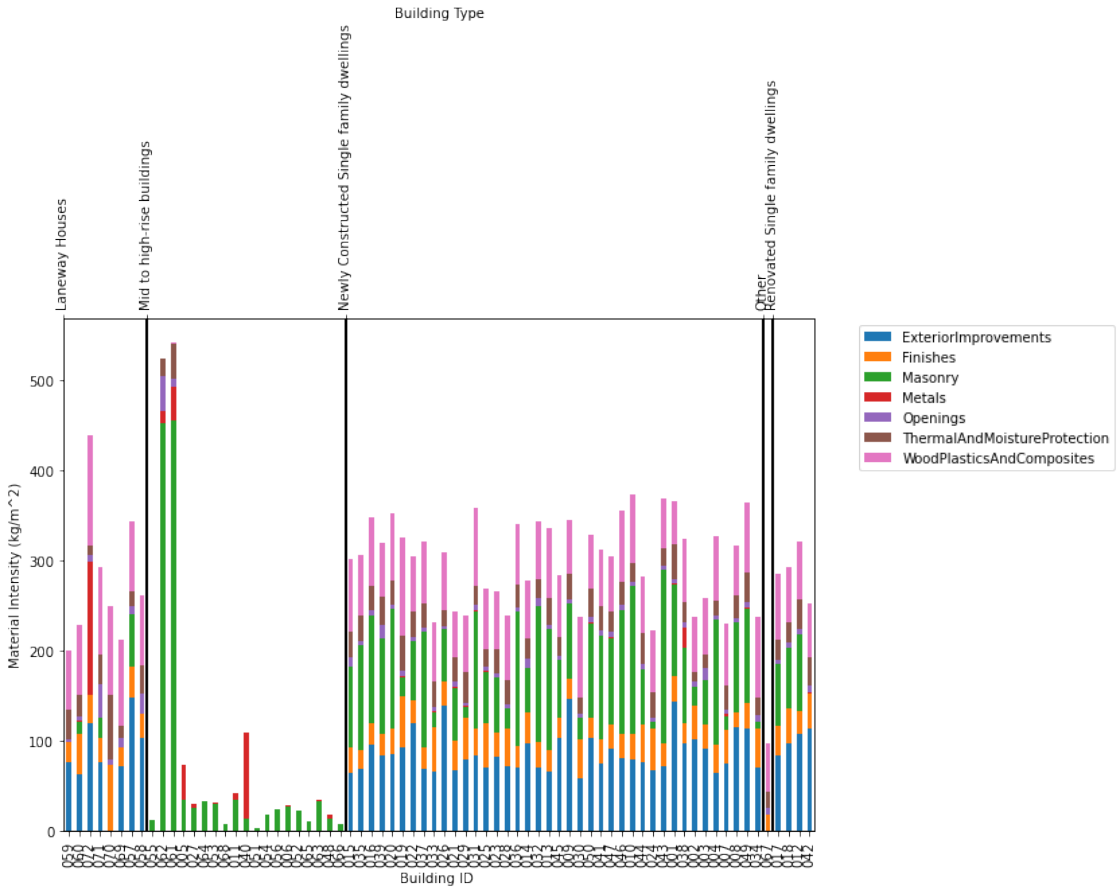
[39]:
```
f = lambda x: master_format_convert[re.split('[_\.\ ]',x)[4]]
toplot = pd.concat([df[headings[1:]],df_mi[kilogram_columns].groupby(f,axis=1).
 ↪sum()],axis=1).sort_values(['Building Type'])
```

[40]:
```
building_type_map = {
    'APB':'Mid to high-rise buildings',
    'EDU':'Mid to high-rise buildings',
    'INS':'Mid to high-rise buildings',
    'MIX':'Mid to high-rise buildings',
    'OFF':'Mid to high-rise buildings',
    'PUF':'Mid to high-rise buildings',
    'TWN':'Other',
    'SND':'Newly Constructed Single family dwellings',
    'SNR':'Renovated Single family dwellings',
    'SMD':'Newly Constructed Single family dwellings',
    'SMR':'Renovated Single family dwellings',
    'ADU':'Other',
    'SEC':'Other',
    'ROW':'Other',
    'LNW':'Laneway Houses'
}

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',
 'PUF',
 'SMD',
 'SMR',
 'SND',
 'SNR',
 'TWN'}
```

[42]:
```
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			
Laneway Houses	128.88	412.96	
Mid to high-rise buildings	39544.96	1121.15	
Newly Constructed Single family dwellings	461.18	396.71	
Other	3566.00	153.88	
Renovated Single family dwellings	277.06	442.97	

Building Identifier	ExteriorImprovements	Finishes	\
Building Type			
Laneway Houses	81.80	35.26	

Mid to high-rise buildings	0.00	0.00
Newly Constructed Single family dwellings	86.16	31.17
Other	0.00	17.91
Renovated Single family dwellings	100.30	33.64

Building Identifier	Masonry	Metals	Openings	\
Building Type				
Laneway Houses	11.68	18.65	12.42	
Mid to high-rise buildings	65.63	10.77	2.53	
Newly Constructed Single family dwellings	83.77	0.96	5.99	
Other	0.00	0.00	7.04	
Renovated Single family dwellings	55.31	0.74	5.84	

Building Identifier	ThermalAndMoistureProtection	\
Building Type		
Laneway Houses	28.81	
Mid to high-rise buildings	3.10	
Newly Constructed Single family dwellings	25.63	
Other	17.50	
Renovated Single family dwellings	26.98	

Building Identifier	WoodPlasticsAndComposites	Total MI
Building Type		
Laneway Houses	89.25	277.86
Mid to high-rise buildings	0.03	82.05
Newly Constructed Single family dwellings	68.82	302.51
Other	54.38	96.83
Renovated Single family dwellings	64.59	287.39

Std Dev Material Intensity:

Building Identifier	Gross Floor Area	Concrete	\
Building Type			
Laneway Houses	50.64	150.56	
Mid to high-rise buildings	33179.20	194.09	
Newly Constructed Single family dwellings	168.17	82.14	
Other	NaN	NaN	
Renovated Single family dwellings	117.28	120.26	

Building Identifier	ExteriorImprovements	Finishes	\
Building Type			
Laneway Houses	43.53	17.14	
Mid to high-rise buildings	0.00	0.00	
Newly Constructed Single family dwellings	22.30	9.40	
Other	NaN	NaN	
Renovated Single family dwellings	12.94	6.38	

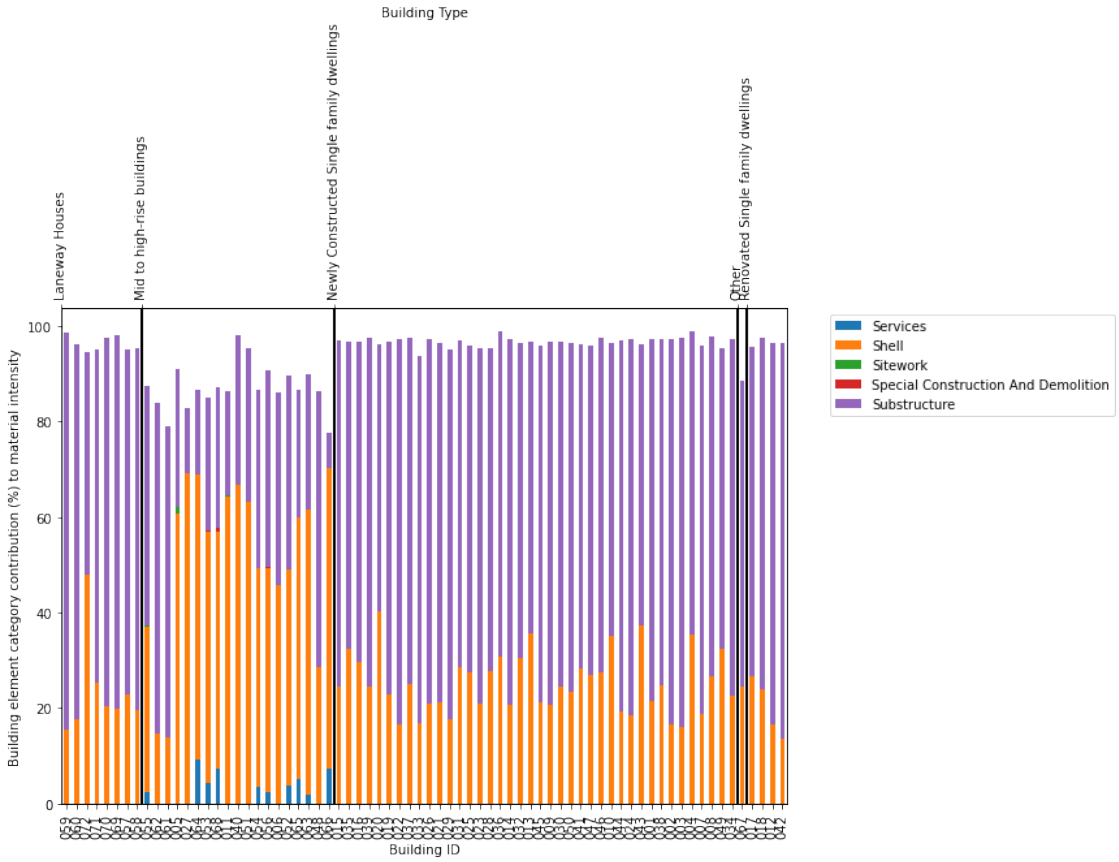
Building Identifier	Masonry	Metals	Openings	\
Building Type				

```
Laneway Houses                                20.51   52.54     11.58
Mid to high-rise buildings                   137.21   23.54      9.04
Newly Constructed Single family dwellings     49.26    3.35      2.21
Other                                           NaN     NaN       NaN
Renovated Single family dwellings             37.88    0.86      1.43

Building Identifier                      ThermalAndMoistureProtection  \
Building Type
Laneway Houses                                                  19.63
Mid to high-rise buildings                                       9.87
Newly Constructed Single family dwellings                        6.14
Other                                                             NaN
Renovated Single family dwellings                                5.44

Building Identifier                      WoodPlasticsAndComposites  Total MI
Building Type
Laneway Houses                                             17.69     79.65
Mid to high-rise buildings                                  0.12    160.80
Newly Constructed Single family dwellings                  11.58     46.39
Other                                                        NaN       NaN
Renovated Single family dwellings                           6.55     28.36
```

[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[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()
```



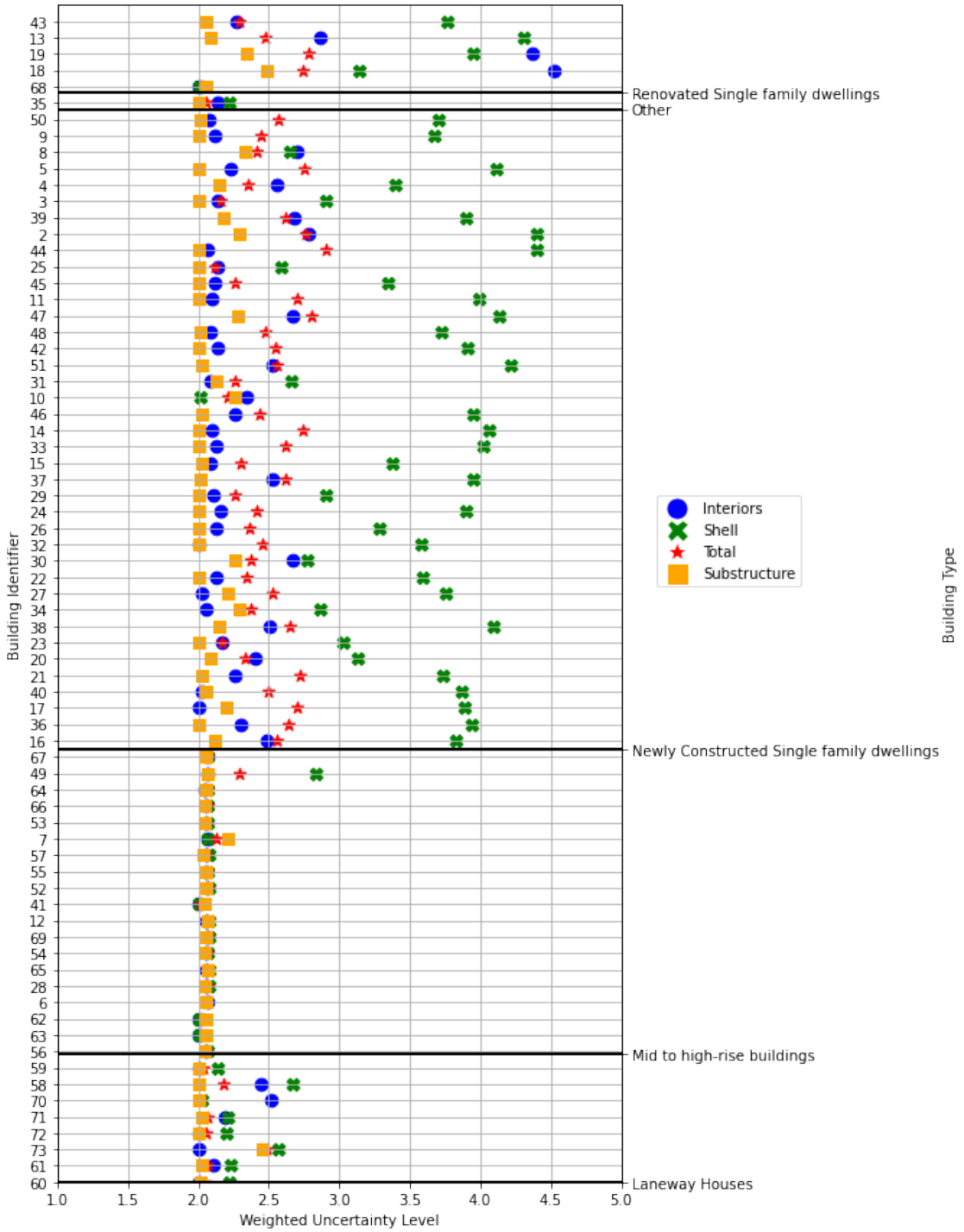
[47]:
```
f = lambda x: name_map[re.split('[_\.\ ]',x)[1][0]] + '/' + re.split('[_\.\␣
 ↪]',x)[-1]
toplot = df_mi[kilogram_columns].groupby(f,axis=1).sum()
```

[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])
# 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	Shell	\
18	60	Laneway Houses	2.000000	0.0	2.222478	

```
17    61                        Laneway Houses   2.106514       0.0  2.229146
16    73                        Laneway Houses   2.000000       0.0  2.571212
11    72                        Laneway Houses   2.005075       0.0  2.200763
12    71                        Laneway Houses   2.190950       0.0  2.206190
..   …                                     …        …       …        …
71    68                                Other   2.000000       0.0  2.000000
68    18  Renovated Single family dwellings   4.523878       0.0  3.139931
69    19  Renovated Single family dwellings   4.371953       0.0  3.946027
30    13  Renovated Single family dwellings   2.868511       0.0  4.306551
70    43  Renovated Single family dwellings   2.275307       0.0  3.763229

    Sitework  Special Construction And Demolition  Substructure     Total
18       0.0                                  0.0      2.009786  2.042591
17       0.0                                  0.0      2.024653  2.063625
16       0.0                                  0.0      2.457455  2.487226
11       0.0                                  0.0      2.000000  2.051110
12       0.0                                  0.0      2.023037  2.064759
..       …                                    …             …       …
71       0.0                                  0.0      2.050328  2.032276
68       0.0                                  0.0      2.480406  2.744405
69       0.0                                  0.0      2.342662  2.777552
30       0.0                                  0.0      2.082720  2.475825
70       0.0                                  0.0      2.056058  2.294809

[72 rows x 9 columns]
```

6 Additional Characteristics

[52]:
```
from collections import Counter
import re
import eeweather
BUILDING_ID = '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(c)
```

```
Counter({'Above Ground': 2, 'Roof': 1, 'Ground': 1, 'Basement': 1})
```

[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]:
```
station.climate_zones
```

[56]:
```
{'iecc_climate_zone': '5',
 'iecc_moisture_regime': 'A',
 'ba_climate_zone': 'Cold',
 'ca_climate_zone': None}
```

[57]:
```
location
```

[57]:
```
Location(Old Toronto, Toronto, Golden Horseshoe, Ontario, Canada, (43.6534817,
-79.3839347, 0.0))
```

[ ]:
```

```