STUDY OF BITUMINOUS PAVEMENTS USING BY-PRODUCTS FROM CARBON BLACK MANUFACTURE

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ACTIVITY 1: PRELIMINARY STUDIES

The following conclusions can be drawn from the articles analysed:

- Mainly tyre pyrolysis carbon black (NCp) is used.
- NCp is mainly incorporated as a bitumen additive **(wet process).**
- The incorporated % of NCp ranges from **5% to 25% by weight of the bitumen.**
- Results obtained by incorporating Ncp.
    - **Reduces susceptibility to Tª**
    - Increases the **Marshall** stability of asphalt mixes (ability to resist deformation).
    - Reduces **rutting** in bitumen
    - Reduces low temperature **cracking**
    - **Increases the tensile strength** of asphalt mixes at low temperatures.
    - On roads with heavy vehicle traffic, **it improves resistance.**
    - In hot climates it **improves the stiffness and elasticity** of bitumens.
    - Improved breaking strength of aged bitumens.
    - Increases the **modulus of elasticity** and decreases the **viscosity of the asphalt**.

ACTIVITY 2.1: *PHYSICO-CHEMICAL CHARACTERISATION OF THE BY-PRODUCT*

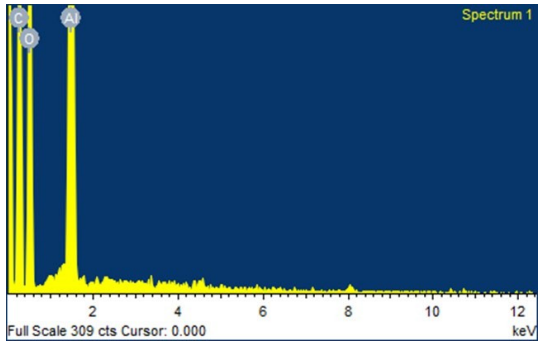
ANALYSED BY-PRODUCT

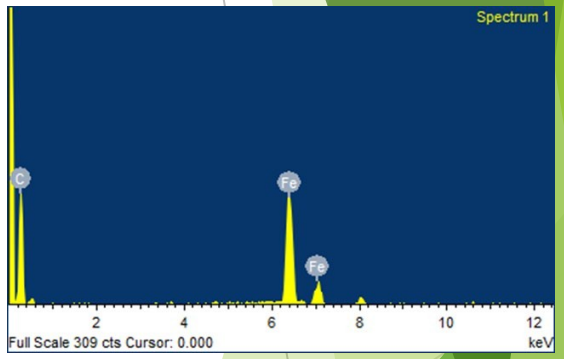
- Material used **WWTP sludge**
- High moisture content
- Pre-treatment is necessary:
  - **Dry in an oven at 110º for 24h.**
  - **Grind and sieve through a 0.5 mm sieve**

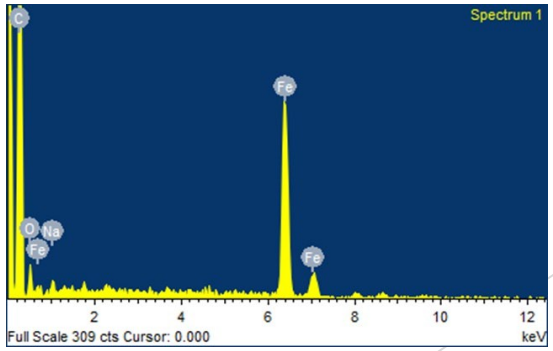
ACTIVITY 2.1: *PHYSICO-CHEMICAL CHARACTERISATION OF THE BY-PRODUCT*

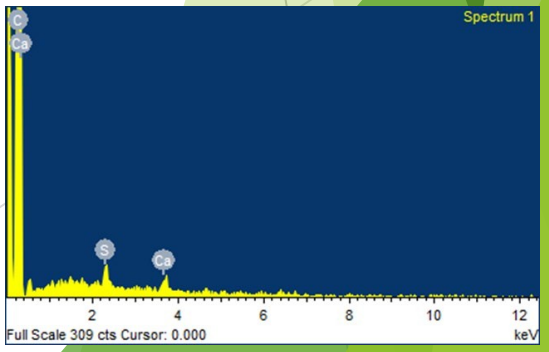
CHEMICAL COMPOSITION

- **SEM** scanning microscope test
- The analysed sample has **"impurities".**
- Impurities detected in the sample:
  - **Aluminium oxide**
  - **Iron residues**
  - **Potassium oxide**
  - **Sulphur oxide**
  - **Copper oxide**
  - **Calcium**









ACTIVITY 2.1: *PHYSICO-CHEMICAL CHARACTERISATION OF THE BY-PRODUCT*

DENSITY

- Test carried out in accordance with UNE - EN - 1097-6 Determination of particle density and water absorption.

- **DENSITY OBTAINED : 1,882 gr/cm3**

HUMIDITY

- Test performed according to UNE - EN - 17892-1:2014 Determination of humidity.

  HUMIDITY OBTAINED : MORE THAN 100%.

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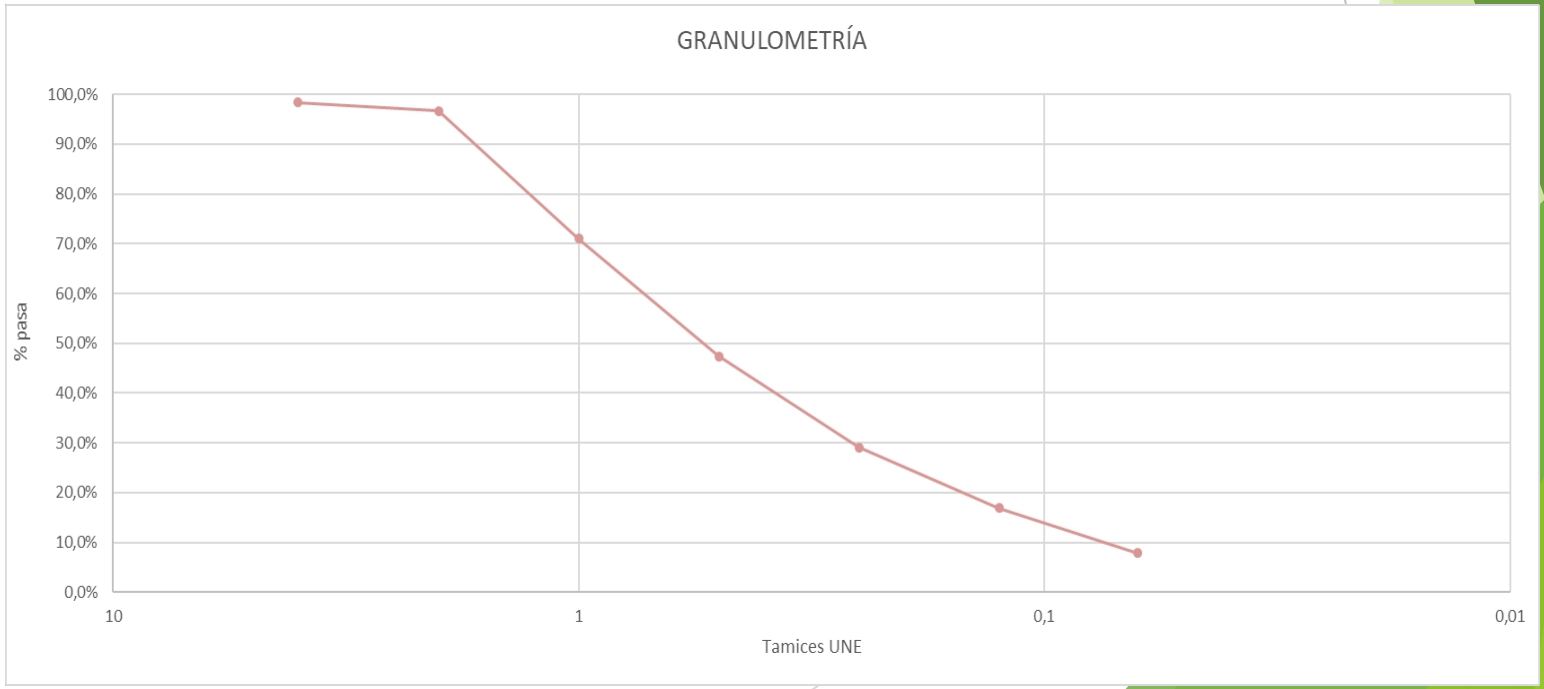
ACTIVITY 2.1: *PHYSICO-CHEMICAL CHARACTERISATION OF THE BY-PRODUCT*

GRANULOMETRY

- Test carried out in accordance with UNE - EN - 933-1 Determination of granulometry. Sieving method.

Sieve opening size mm	Mass of retained material $(R)_1$ grams	Cumulative percentages passing $100 - \Sigma \frac{Ri}{M} \frac{Ri}{i} \times 100$
0,500	**0,0**	100%
0,250	**27,6**	61,5%
0,125	**45,6**	36,3%
0,063	**59,8**	16,5%
P = Background	**79,4**	



ACTIVITY 2.1: *PHYSICO-CHEMICAL CHARACTERISATION OF THE BY-PRODUCT*

RESULTS OBTAINED

- From the analysis of the chemical composition it is concluded that the elements present in the by-product such as iron, aluminium, sodium, potassium... are impurities and have little influence on the sample.

- Since the **density of the by-product (1,882 $^{g/cm3}$)** is higher than that of bitumen (1,031 $^{g/cm3}$), the carbon black by-product will decant when mixed with bitumen.

- Due to the high moisture content of the by-product, it is necessary to dry, grind and sieve it in order to work with it.

- Based on the results obtained from the granulometry, **the by-product is not considered as a substitute material for filler only.** Taking into account the size of the by-product, **it will be used as a substitute for fine aggregate**, all of which passes through 0.5mm.

ACTIVITY 2.2: MECHANICAL BEHAVIOUR AND RELUBRICATION OF BINDERS

Working methodology analysis of unaged/aged binders :

1º Reference bitumen: REPSOL 50/70

2nd Bitumen reference + % NC (5%, 10%,12%, 15%, 20%)
NC sieving with 0,5 mm sieve

3º Reference bitumen + filler

5º Reference bitumen + cement

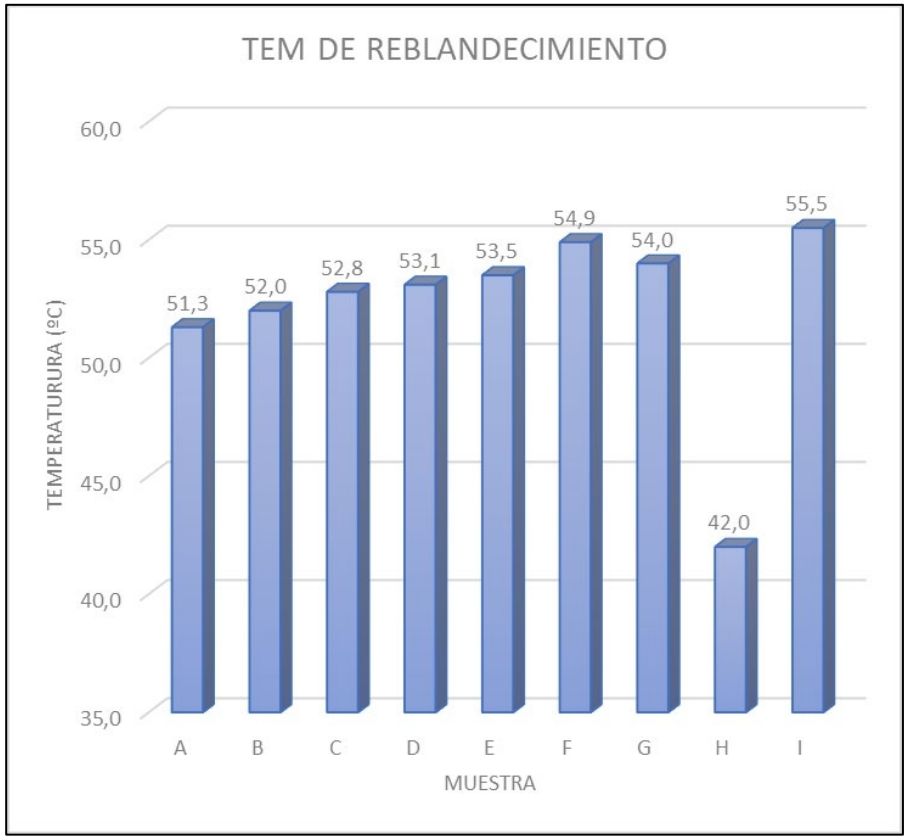
- **Rheometer.**
- **Binder penetration.**
- **Softening temperature of binders.**

4th Comparison of results

ACTIVITY 2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

ACTIVITY 2.2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

RESULTS OBTAINED WITHOUT AGEING



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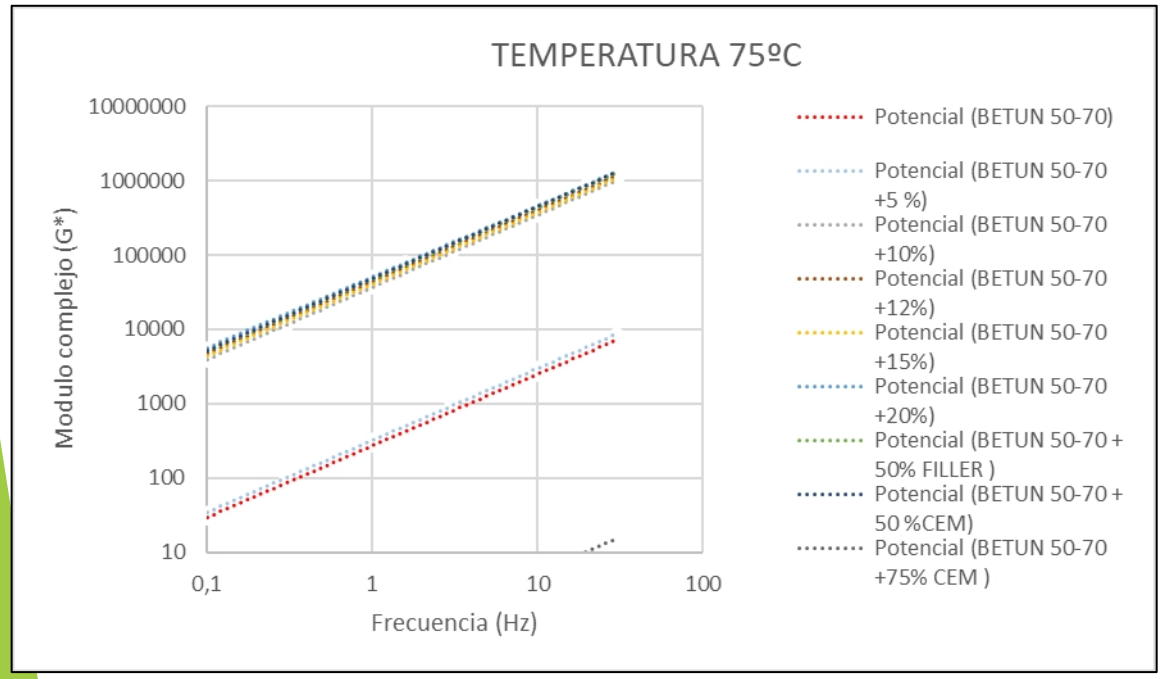
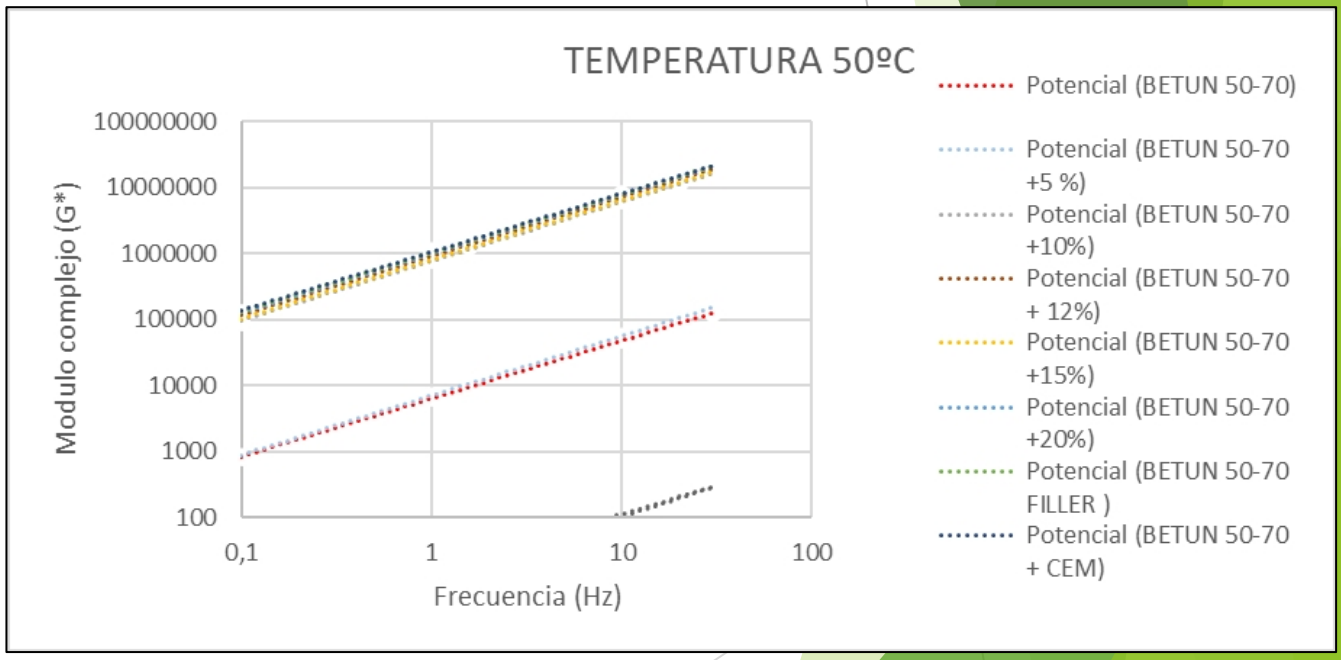
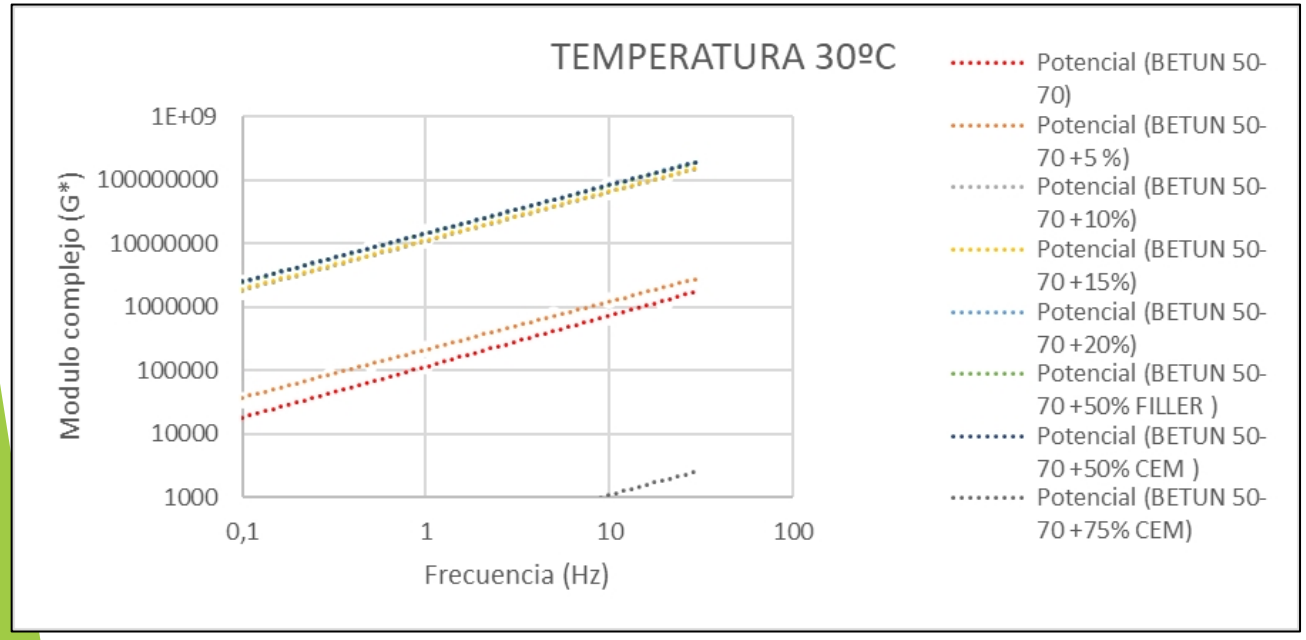
RESULTS OBTAINED WITHOUT AGEING

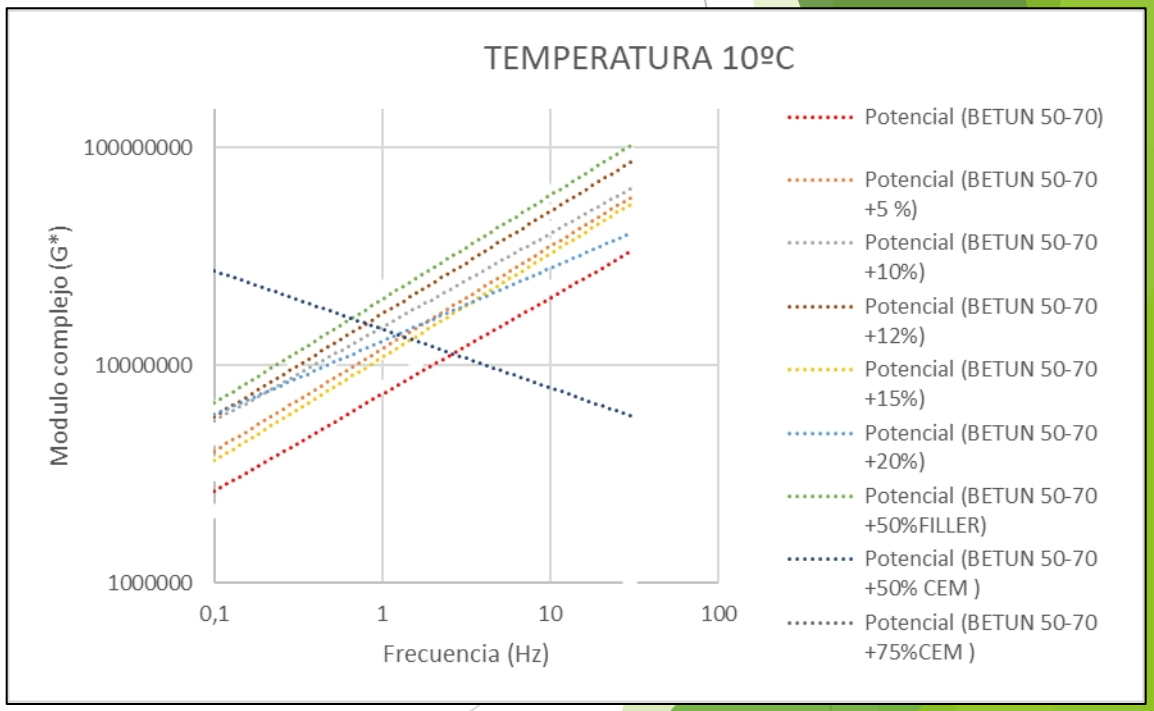




ACTIVITY 2.2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

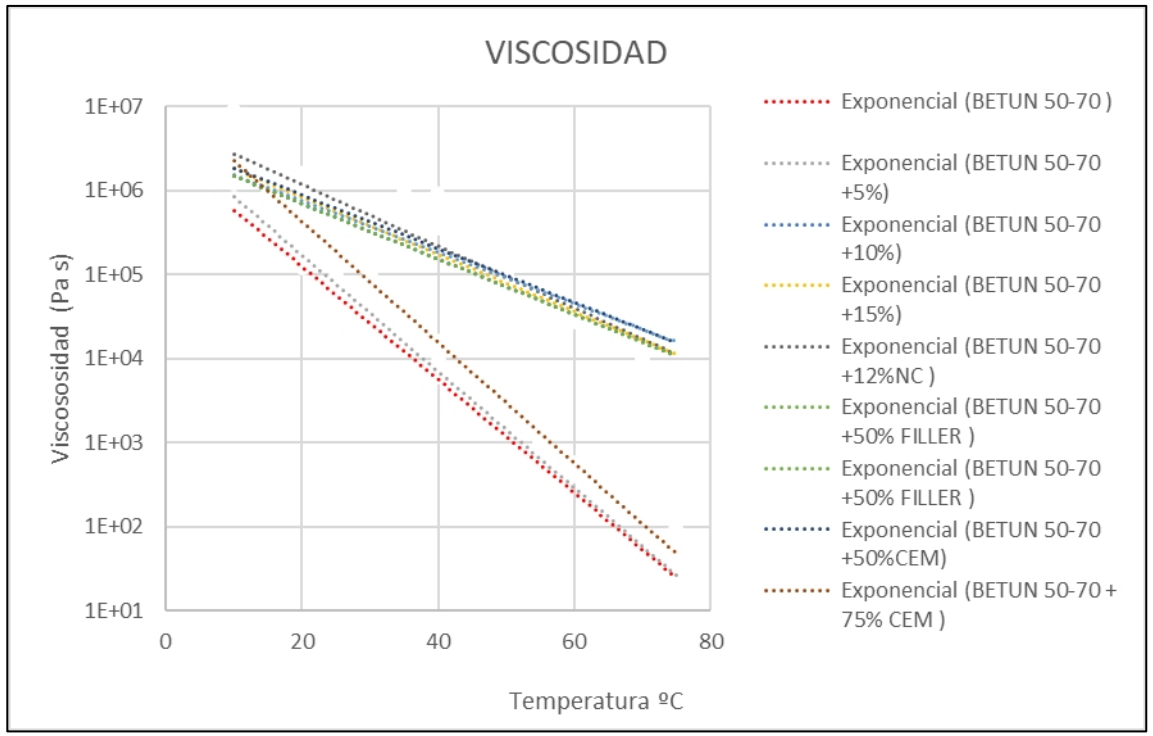
RESULTS OBTAINED WITHOUT AGEING





ACTIVITY 2.2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

RESULTS OBTAINED VISCOSITY WITHOUT AGEING



	ECUATION	R^2
BETUN 50-70	$\eta = 3E+06e^{-0,155T}$	0,9722
BITUMEN 50-70+ 5% BITUMEN	$\eta = 4E+06e^{-0,159T}$	0,9697
BITUMEN 50-70 +10	$\eta = 3E+06e^{-0,076T}$	0,6182
BITUMEN 50-70 +12% +12	$\eta = 6E+06e^{-0,085}$	0,6596
BITUMEN 50-70 +15 % +15	$\eta = 4E+06e^{-0,078T}$	0,5975
BITUMEN 50-70+20	$\eta = 3E+06e^{-0,07T}$	0,5691
BITUMEN 50-70+ FILLER	$\eta = 3E+06e^{-0,076T}$	0,6182
BITUMEN 50-70 + CEM 50%.	$\eta = 4E+06e^{-0,073T}$	0,5518
BITUMEN 50-70 + CEM 75%.	$\eta = 1E+07e^{-0,166T}$	0,9687

ACTIVITY 2.2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

AGEING OF BITUMENS

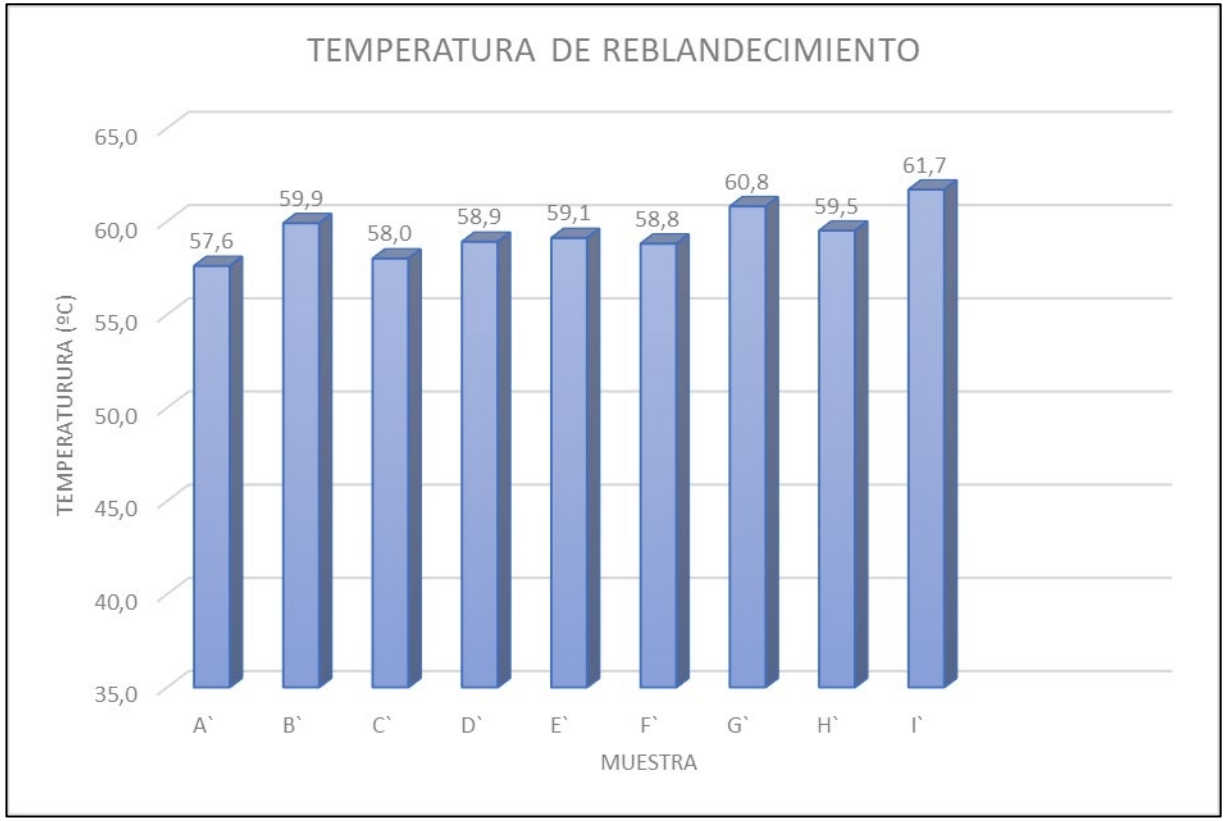
Simulate the deterioration of bitumens over time u n d e r temperature and pressure conditions.

- **SHORT-TERM AGEING.** Rotating thin film and rotating thin film test (RTOF). It represents the ageing that a bituminous binder undergoes during handling, storage, mixing and paving of asphalt mixtures.

- **LONG-TERM AGEING.** Pressure ageing test (PAV) PAV ageing attempts to simulate the degree of hardening that bitumen undergoes after several years in service.

ACTIVITY 2.2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

SHORT-TERM AGEING RESULTS



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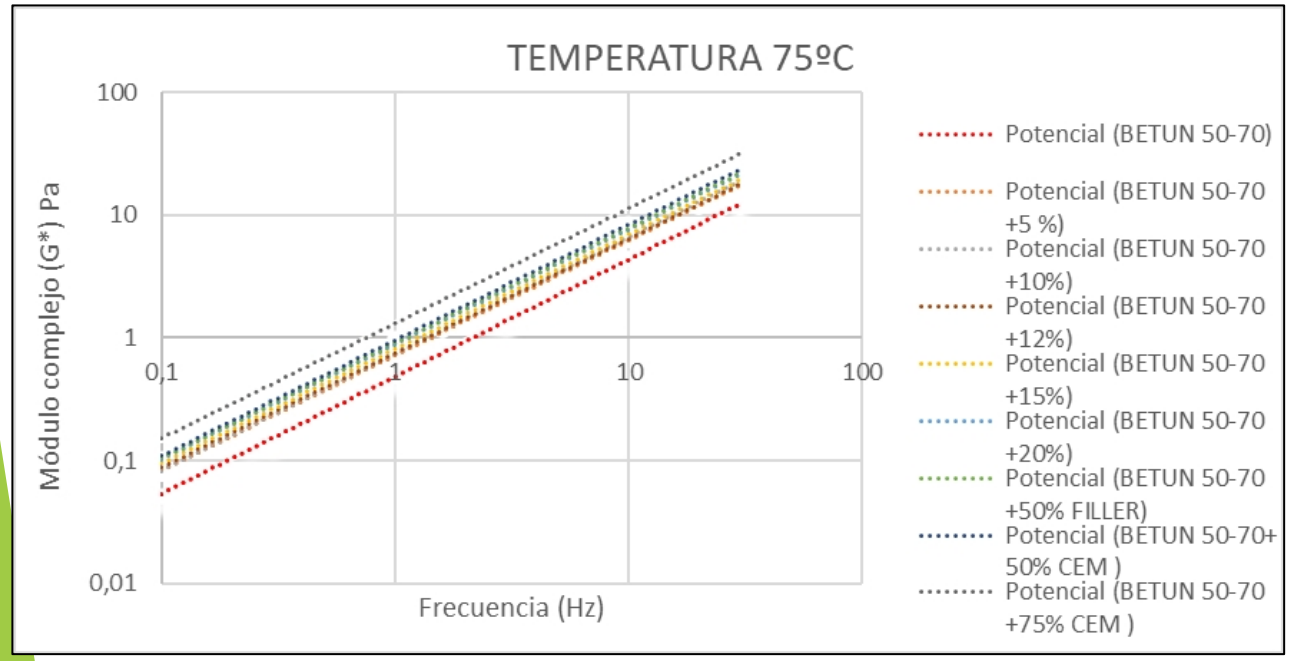
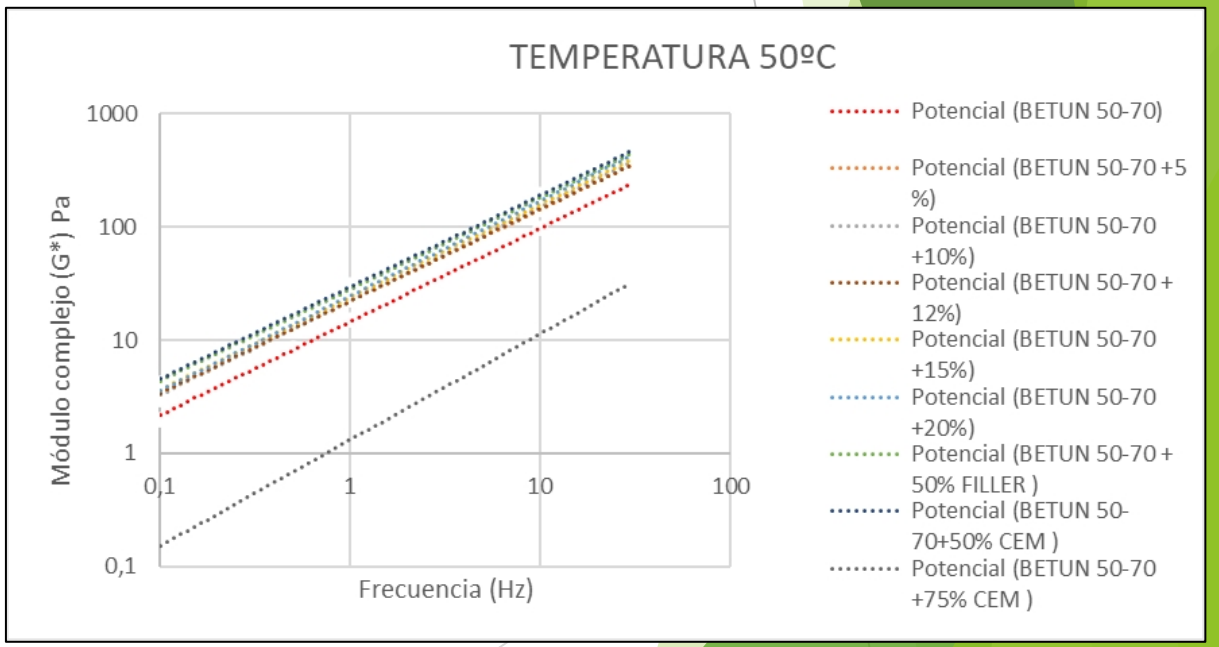
SHORT-TERM AGEING RESULTS





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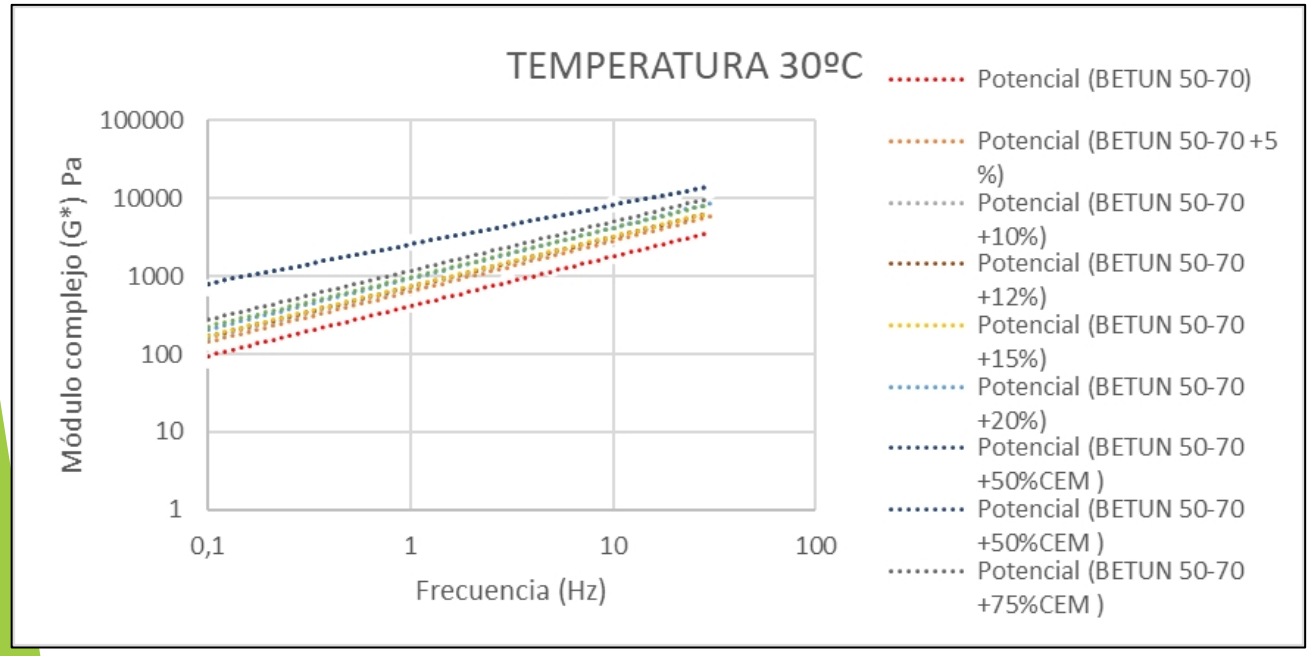
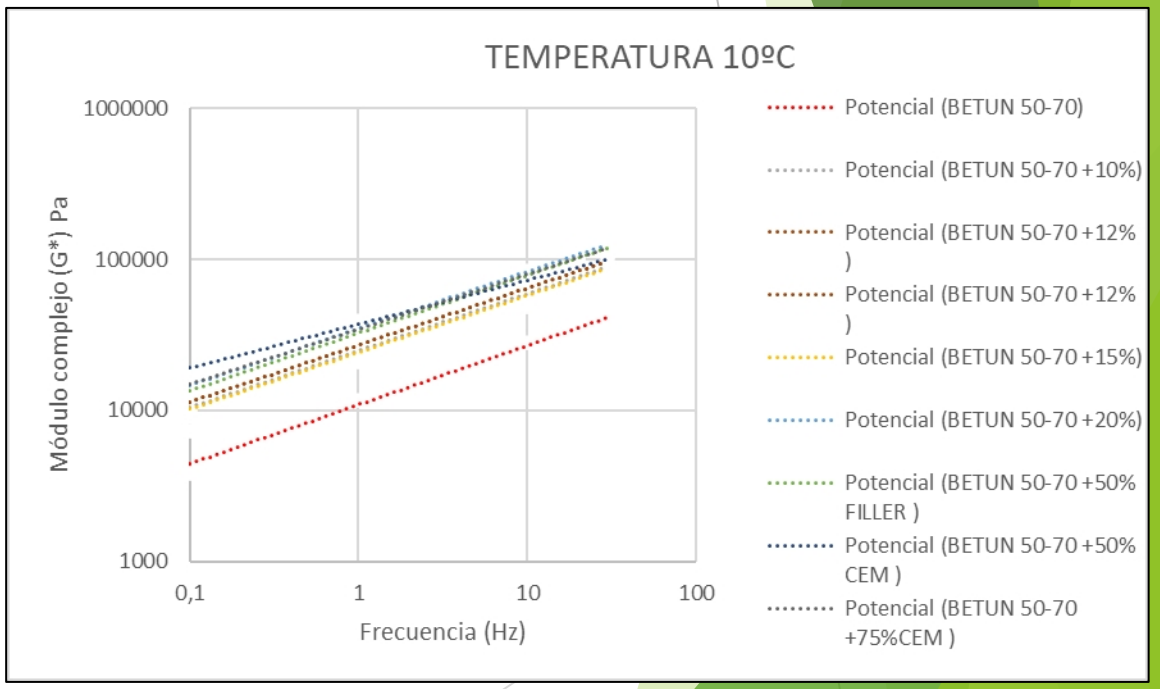
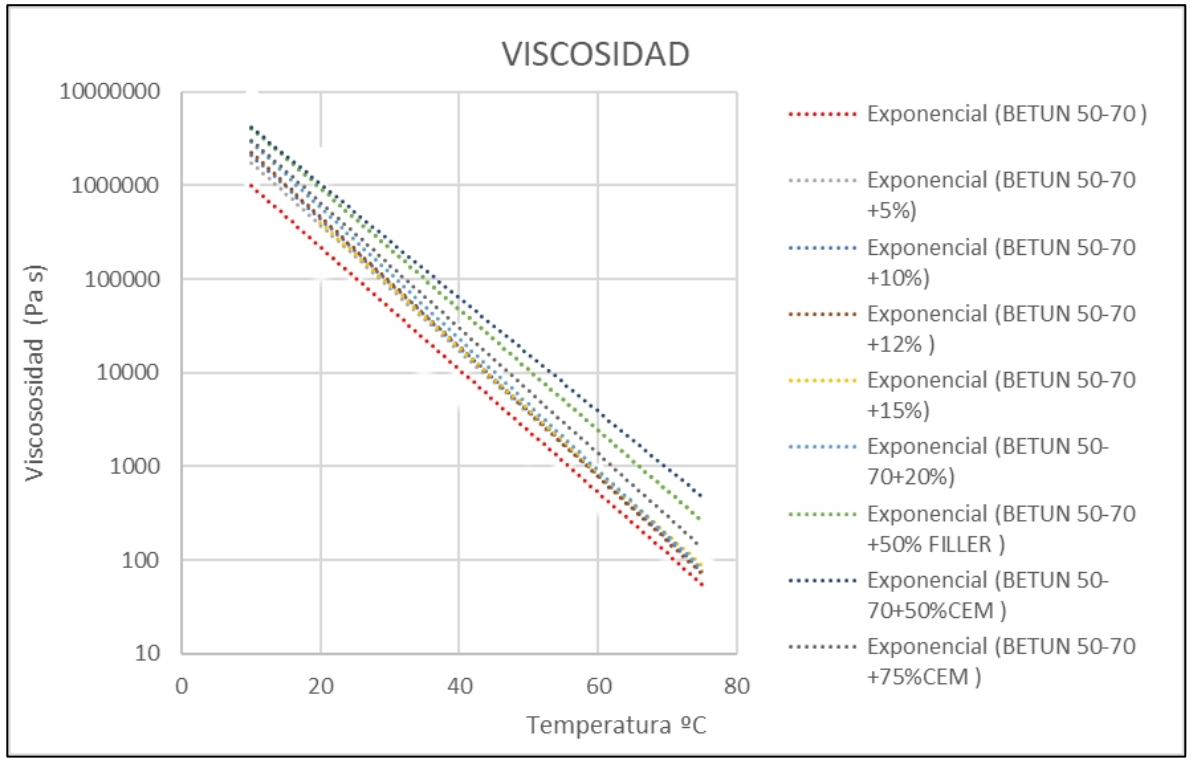
SHORT-TERM AGEING RESULTS





ACTIVITY 2.2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

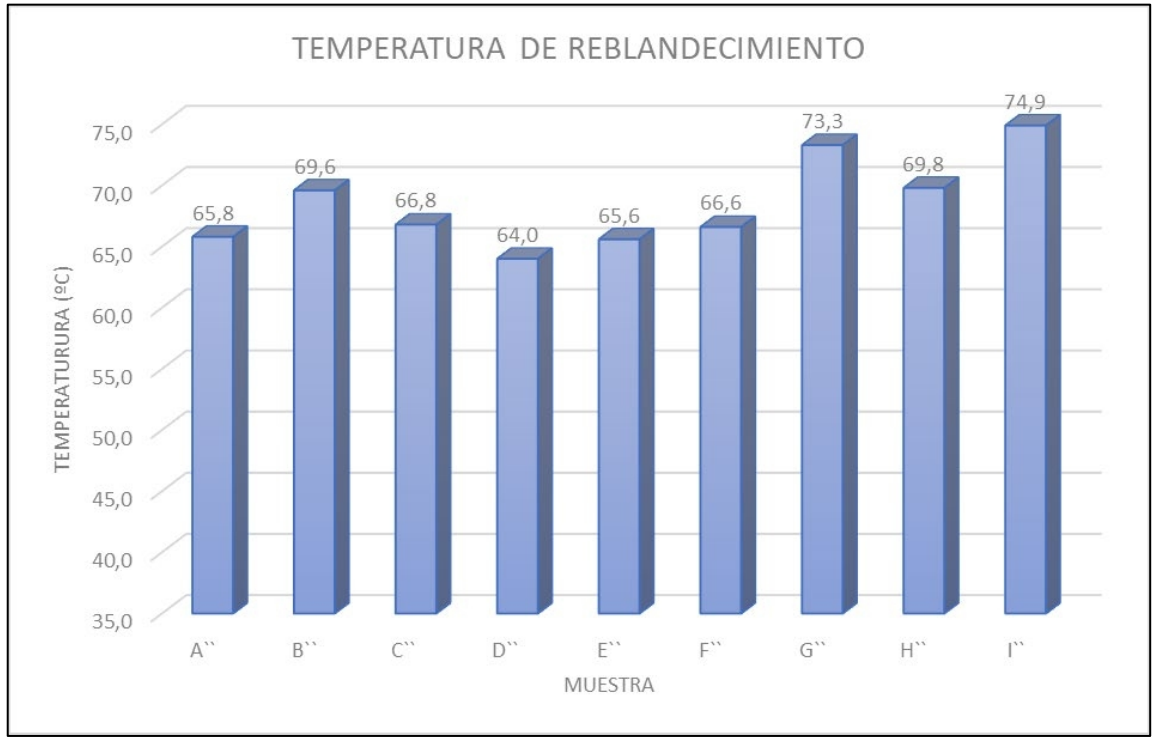
RESULTS VISCOSITY SHORT TERM AGEING



	ECUATION	R^2
BETUN 50-70	$\eta = 4E+06e^{-0,151T}$	0,9607
BITUMEN 50-70 +5	$\eta = 8E+06e^{-0,154T}$	0,9603
BITUMEN 50-70 +10	$\eta = 1E+07e^{-0,158T}$	0,9621
BITUMEN 50-70 +12	$\eta = {}^{4E+06e-0,1536T}$	0,9607
BITUMEN 50-70 +15 %+15	$\eta = 9E+06e^{-0,161T}$	0,9629
BITUMEN 50-70+20	$\eta = 1E+07e^{-0,07T}$	0,9621
BITUMEN 50-70+ FILLER	$\eta = 2E+07e^{-0,149T}$	0,9384
BITUMEN 50-70 + CEM 50%.	$\eta = 2E+0e-0^{,140T}$	0,9264
BITUMEN 50-70 + CEM 75%.	$\eta = 1E+07e^{-0,154T}$	0,9586

ACTIVITY 2.2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

LONG-TERM AGEING RESULTS



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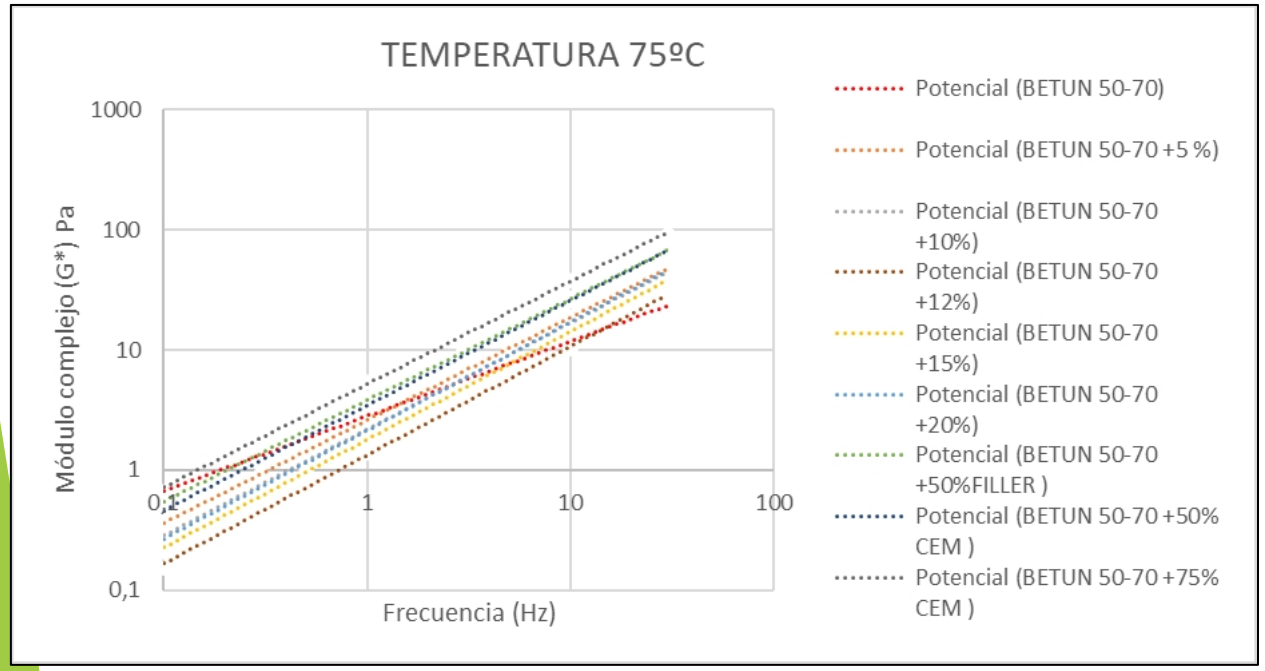
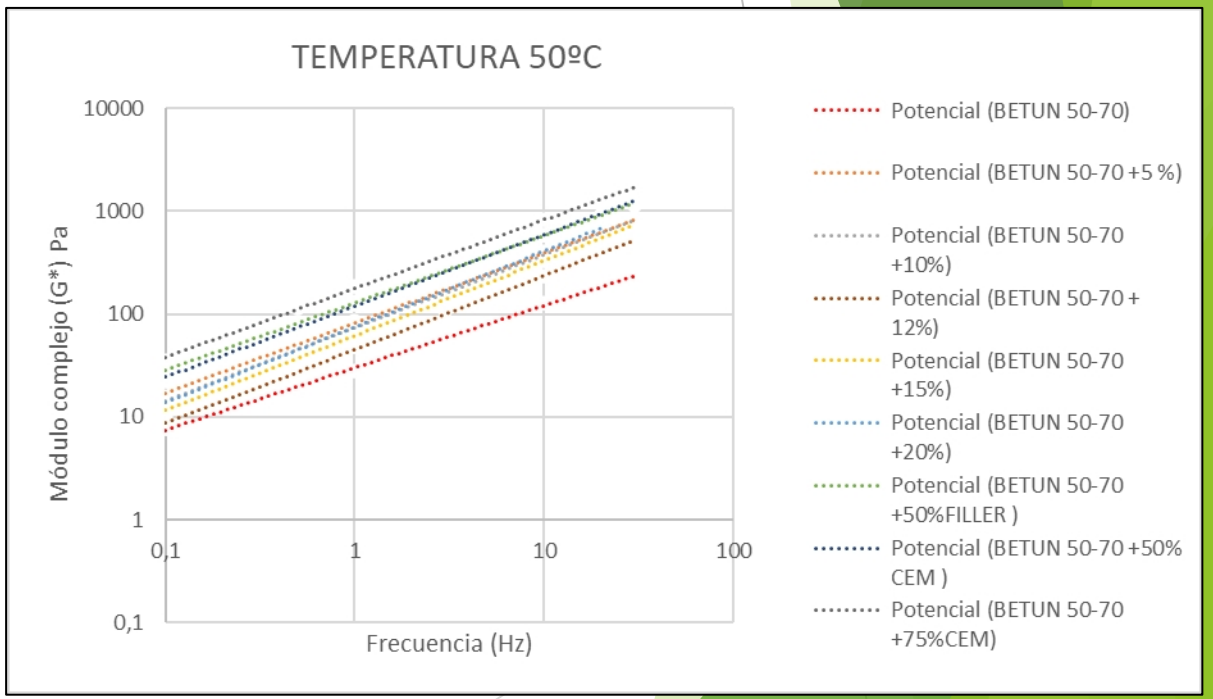
LONG-TERM AGEING RESULTS





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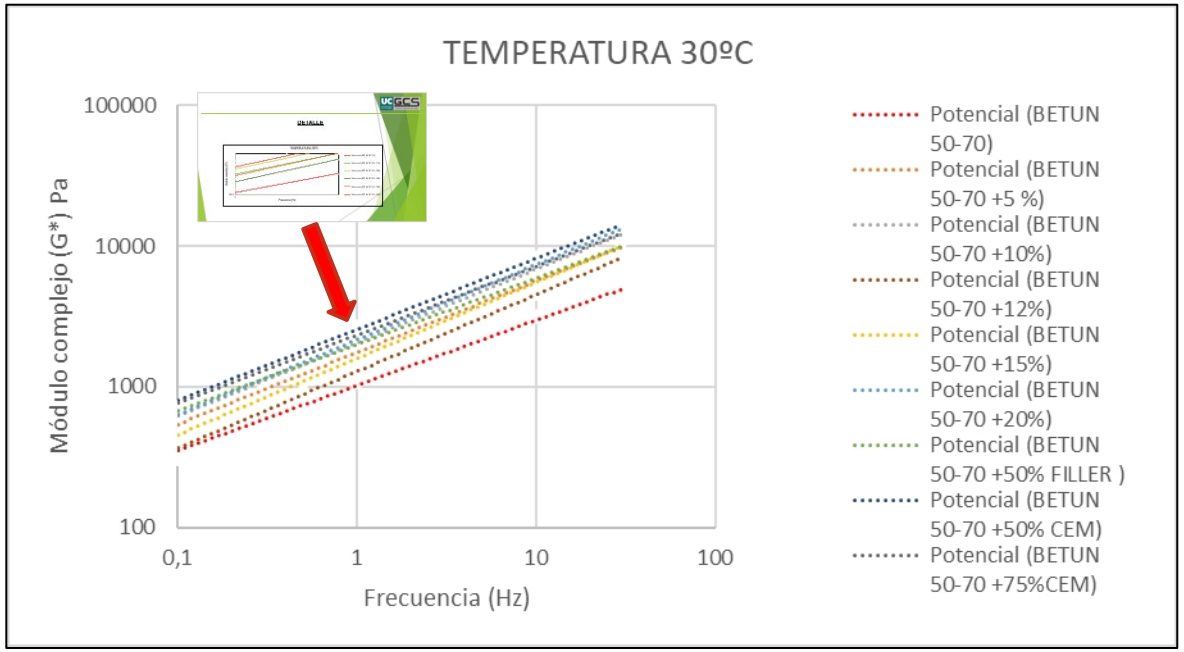
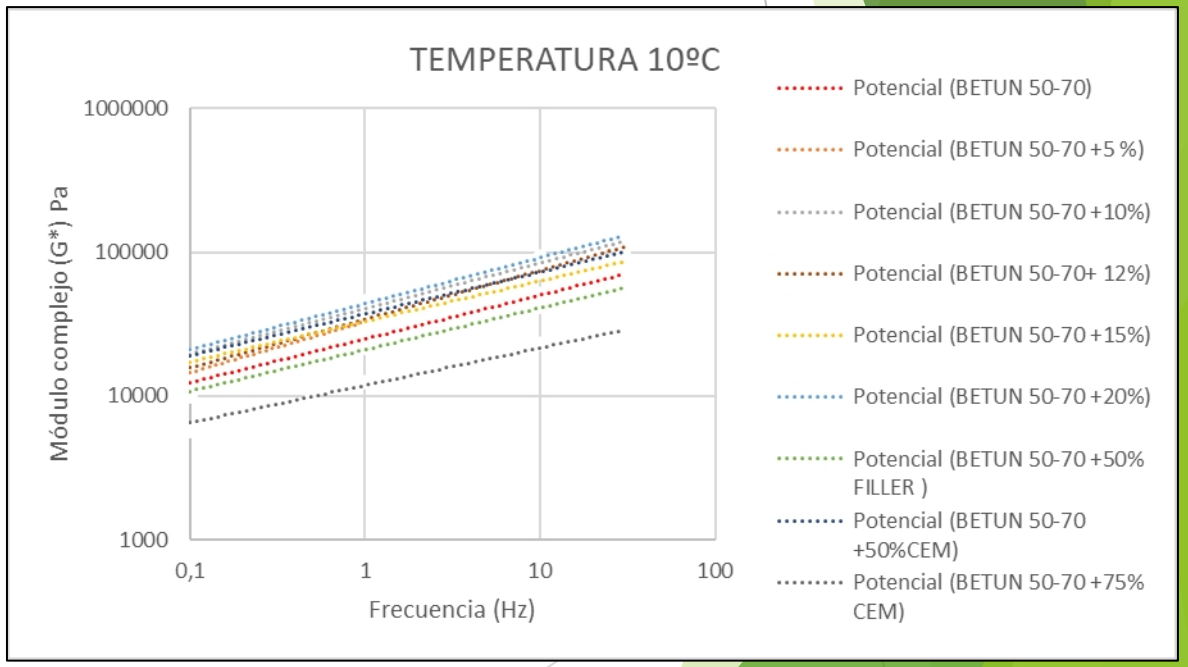
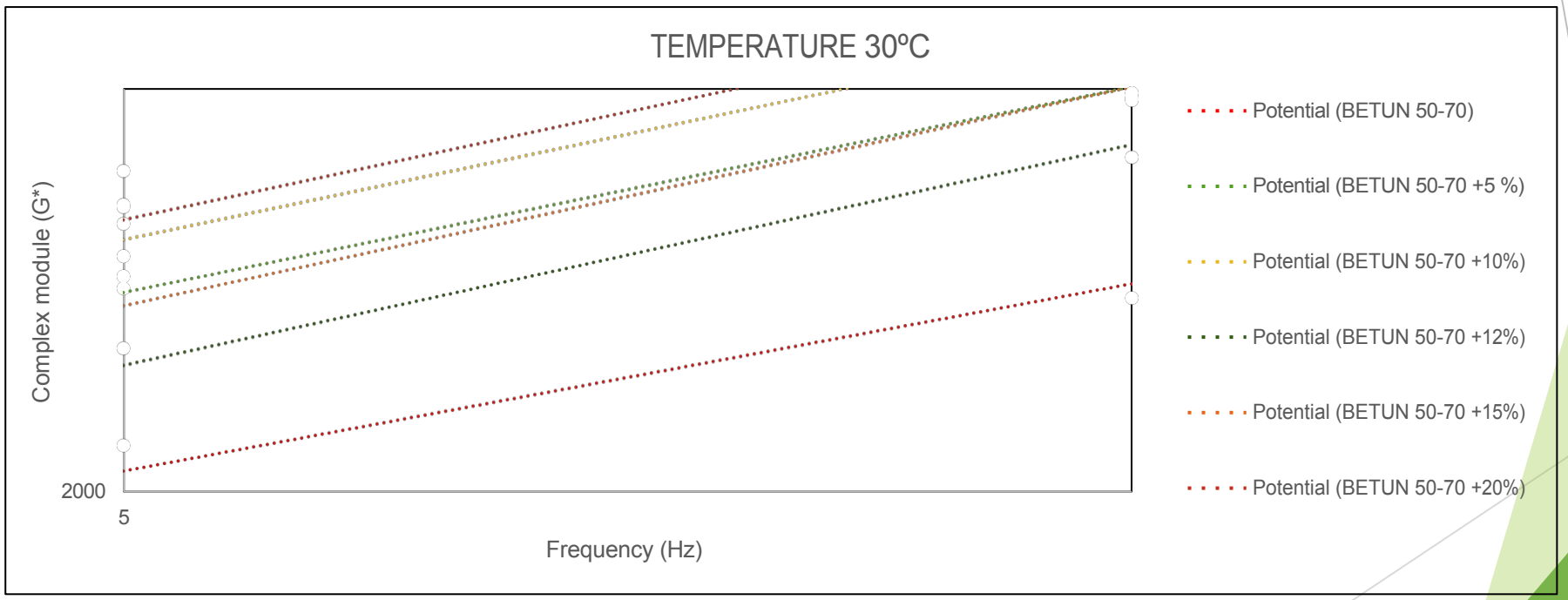
LONG-TERM AGEING RESULTS



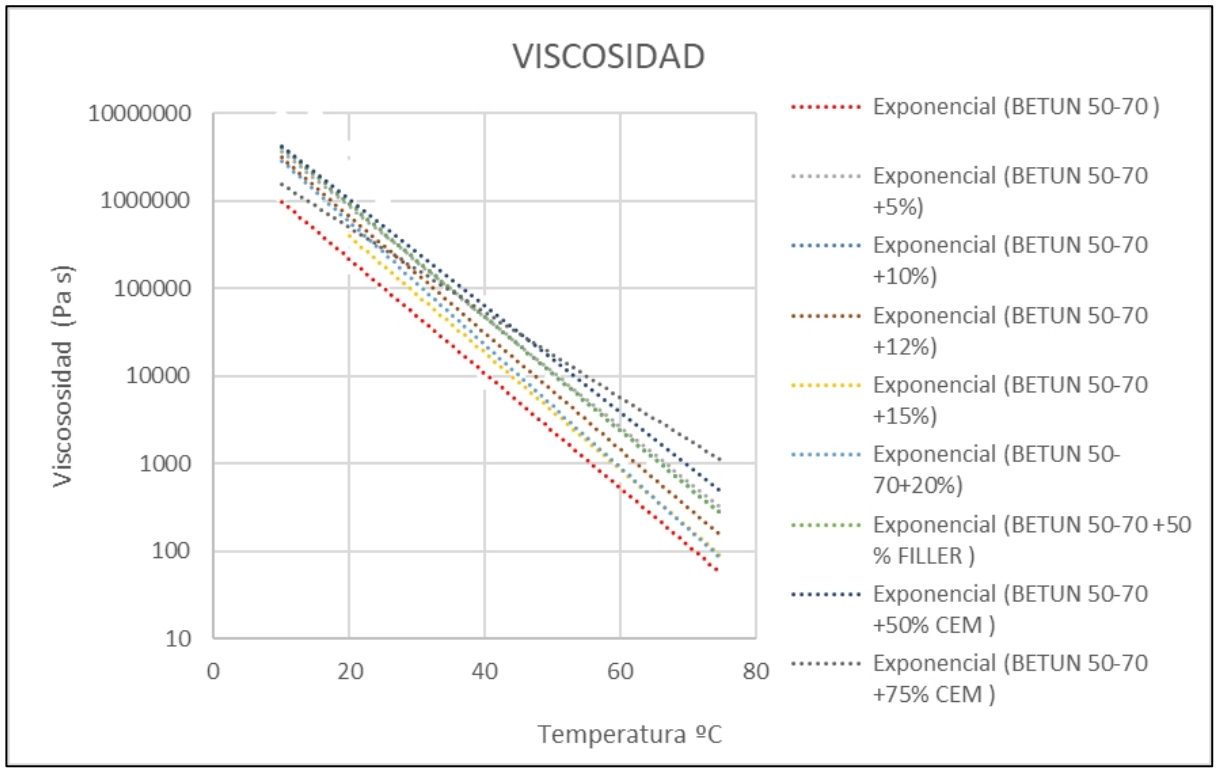


DETAIL


TEMPERATURE 30ºC
Complex module (G*)
2000
5
Frequency (Hz)
Potential (BETUN 50-70)
Potential (BETUN 50-70 +5 %)
Potential (BETUN 50-70 +10%)
Potential (BETUN 50-70 +12%)
Potential (BETUN 50-70 +15%)
Potential (BETUN 50-70 +20%)

ACTIVITY 2.2: MECHANICAL AND RHEOLOGICAL BEHAVIOUR OF BINDERS

RESULTS VISCOSITY LONG-TERM AGEING



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BITUMEN 50-70 +12	$\eta = 1E+07e^{-0,153T}$	0,9443
BITUMEN 50-70 +15 %+15	$\eta = 9E+06e^{-0,153T}$	0,9629
BITUMEN 50-70+20	$\eta = 41+06e^{-0,161T}$	0,9621
BITUMEN 50-70+ FILLER	$\eta = 2E+06e^{-0,149T}$	0,9384
BITUMEN 50-70 + CEM 50%.	$\eta = 2E+06e^{-0,14T}$	0,9264
BITUMEN 50-70 + CEM 75%.	$\eta = 5E+06e^{-0,112T}$	0,8485

CONCLUSIONS

- From the **SHORT-TERM AGING** it can be concluded that as we increase the % of NC by-product**, the penetration and softening temperature values remain constant**.
- **At low temperatures the complex modulus G* increases and** the strength of the binder improves.
- From the analysis of **LONG-TERM AGEING it** can be concluded that as the **%** of by-product **increases**, the **values of penetration and softening temperature** remain **constant.**

From the analysis of the **SHORT-TERM AGING** rheometer it can be seen that by mixing the reference bitumen

- with different percentages of NC the **complex modulus increases as the % of NC increases.**

At low temperatures the complex modulus G* increases and the strength of the binder improves.

- The percentage of NC to be used to make asphalt mixes for the following activities i s between **10-12% by**
- **weight of the bitumen.**

THANK YOU FOR YOUR ATTENTION