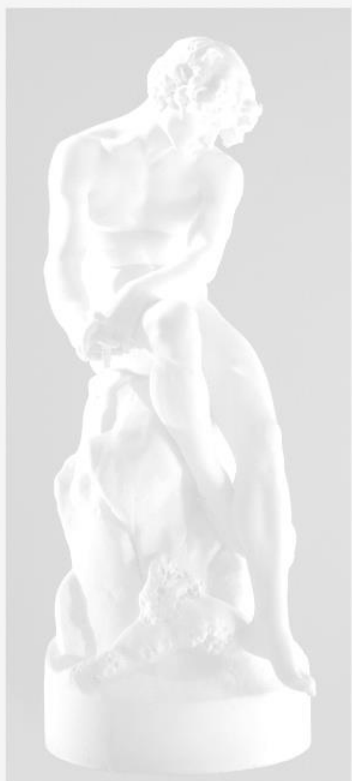


# SCULPT 2021

Shaping Genealogies  
1<sup>st</sup> International Conference on  
Late 19<sup>th</sup> and Early 20<sup>th</sup> Century Sculpture



## **Exploring portable Ultrasonic Pulse Velocity avails in the Conservation Assessment of Plaster Sculptures in Museum environment**

**A. Mário Almeida**

Universidade do Minho

**Mário Pereira**

Universidade do Minho

**Graça Vasconcelos**

Universidade do Minho

**Salomé Carvalho**

Soares dos Reis National Museum / Universidade Católica Portuguesa

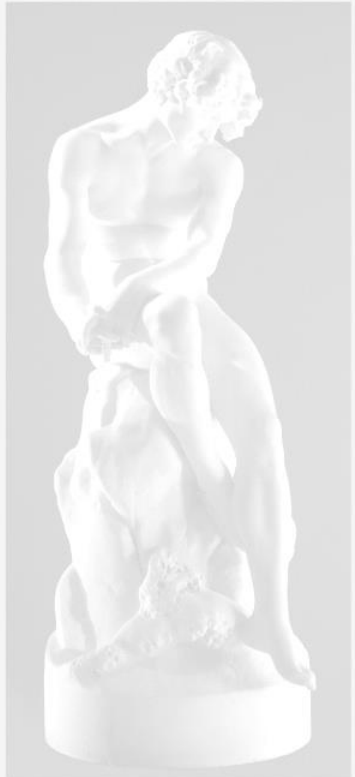
**Rui Bordalo**

Universidade Católica Portuguesa

**Eduarda Vieira**

Universidade Católica Portuguesa

# SCULPT 2021



## Application of Ultrasonic Pulse Velocity for the Condition Assessment of Plaster Sculptures: a preliminary study

**Geo SR** – Multidisciplinary approach to alteration, alterability and conservation of Soares dos Reis' geomaterial sculpture

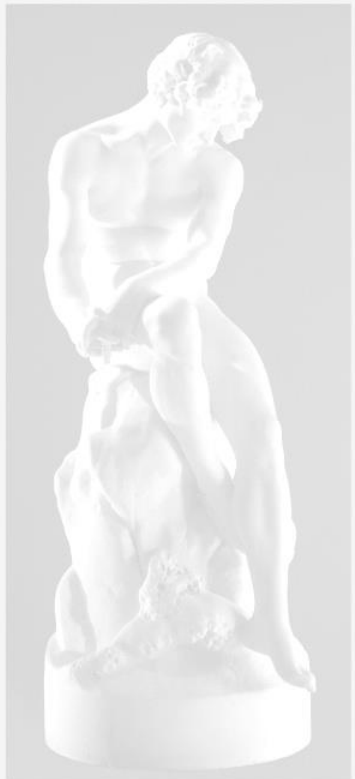
Breaking boundaries in museum paradigms and creating value in changing societies through culture

ONLINE  
7-8 OCT 2021

PTDC/ART-OUT/31304/2017/POCI-01-0145-FEDER-031304

# SCULPT 2021

## **Application of Ultrasonic Pulse Velocity for the Condition Assessment of Plaster Sculptures: a preliminary study**

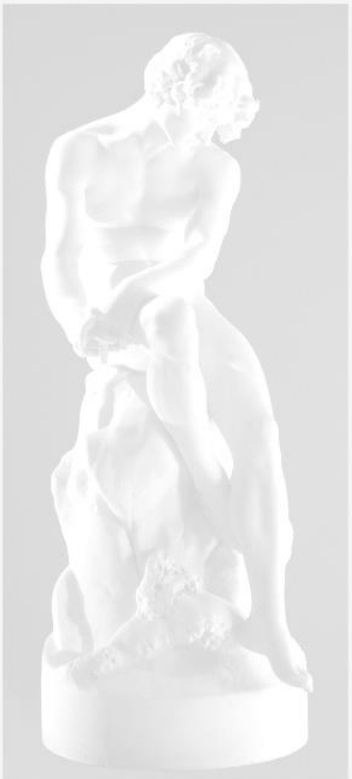


**Geo SR – UPV studies of Soares dos Reis plaster sculptures**

ONLINE  
7-8 OCT 2021

# SCULPT 2021

## Application of Ultrasonic Pulse Velocity for the Condition Assessment of Plaster Sculptures: a preliminary study



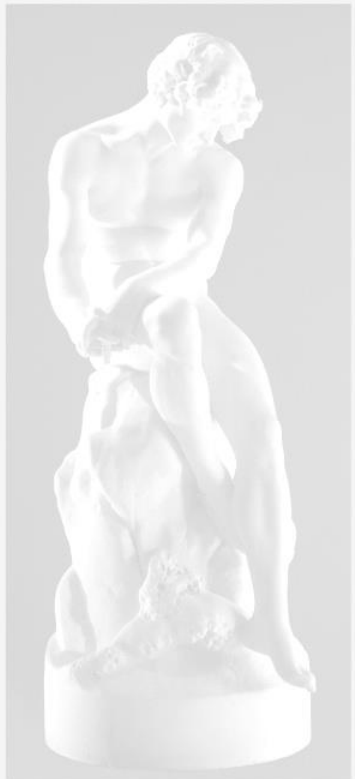
**Geo SR** – UPV studies of Soares dos Reis plaster sculptures

**1 Noninvasive**

ONLINE  
7-8 OCT 2021

# SCULPT 2021

## Application of Ultrasonic Pulse Velocity for the Condition Assessment of Plaster Sculptures: a preliminary study



**Geo SR** – UPV studies of Soares dos Reis plaster sculptures

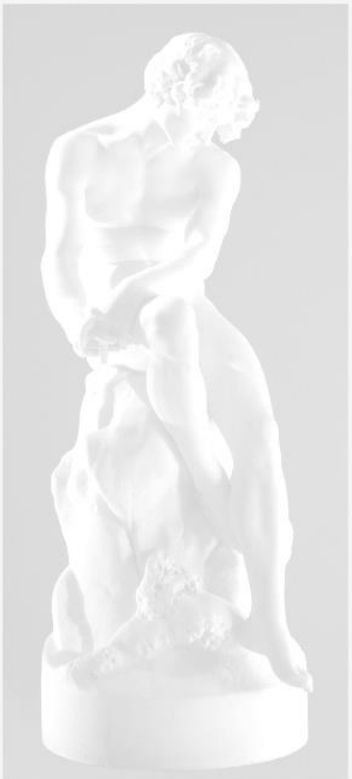
1 **Noninvasive**

2 *In situ*

ONLINE  
7-8 OCT 2021

# SCULPT 2021

## Application of Ultrasonic Pulse Velocity for the Condition Assessment of Plaster Sculptures: a preliminary study



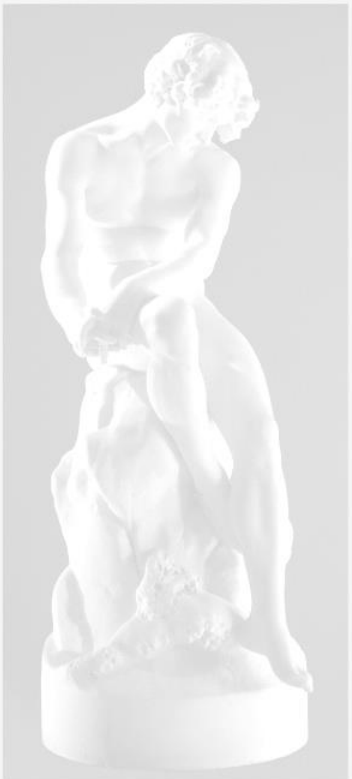
**Geo SR** – UPV studies of Soares dos Reis plaster sculptures

- 1 **Noninvasive**
- 2 *In situ*
- 3 Test a convenient **coupling material**

ONLINE  
7-8 OCT 2021

# SCULPT 2021

## Application of Ultrasonic Pulse Velocity for the Condition Assessment of Plaster Sculptures: a preliminary study



**Geo SR** – UPV studies of Soares dos Reis plaster sculptures

- 1 **Noninvasive**
- 2 *In situ*
- 3 Test a convenient **coupling material**
- 4 **Reliable** measurements, **reproducible** and **straightforward to interpret**



Available online at

**ScienceDirect**

[www.sciencedirect.com](http://www.sciencedirect.com)

Elsevier Masson France

**EM|consulte**

[www.em-consulte.com/en](http://www.em-consulte.com/en)



Original article

# Crack assessment in marble sculptures using ultrasonic measurements: Laboratory tests and application on the statue of David by Michelangelo

Giovanni Pascale<sup>a,\*</sup>, Antonio Lolli<sup>b</sup>

<sup>a</sup> Department DICAM, School of Engineering and Architecture, University of Bologna, Bologna, Italy

<sup>b</sup> CIRI-Inter-Department Research Center for Construction, Bologna, Italy



## ARTICLE INFO

*Article history:*

Received 8 August 2014

Accepted 9 February 2015

Available online 13 March 2015

## ABSTRACT

The large marble statues can suffer serious fractures, due to the stress states originated by the weight and the shape, often thin and articulated. Fractures are often triggered by surface cracking. For this reason, it is important to assess the severity of the apparent cracks, by performing periodic nondestructive surveys. The ultrasonic method is well suited for this purpose. This paper presents a research activity finalized at improving the application of the ultrasound method to the detection of crack depth in marble elements.





Available online at  
**ScienceDirect**  
www.sciencedirect.com

Elsevier Masson France  
**EM|consulte**  
www.em-consulte.com/en



Original article

## Crack assessment in marble sculptures using ultrasonic measurements: Laboratory tests and application on the statue of David by Michelangelo

Giovanni Pascale<sup>a,\*</sup>, Antonio Lolli<sup>b</sup>

<sup>a</sup> Department DICAM, School of Engineering and Architecture, University of Bologna, Bologna, Italy

<sup>b</sup> CIRI-Inter-Department Research Center for Construction, Bologna, Italy



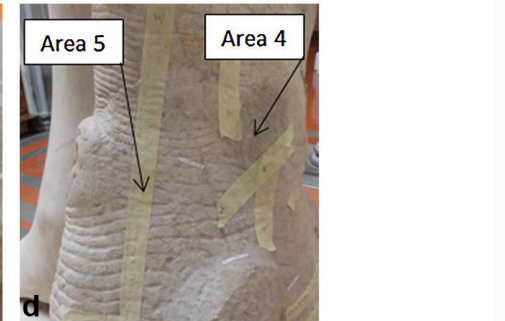
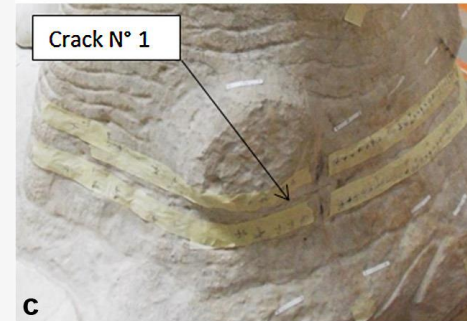
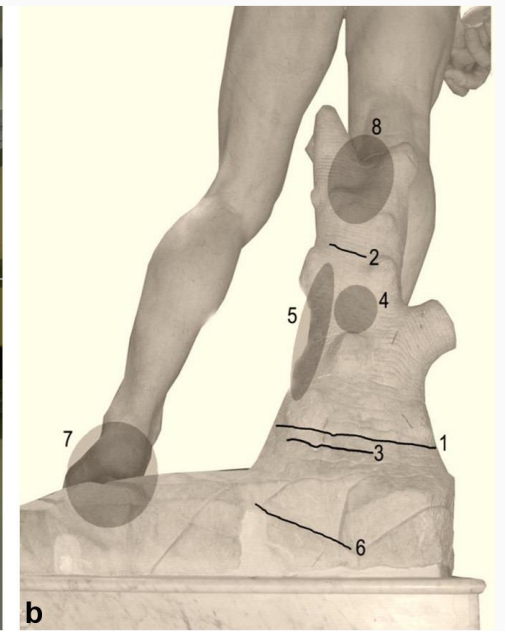
### ARTICLE INFO

*Article history:*  
Received 8 August 2014  
Accepted 9 February 2015  
Available online 13 March 2015

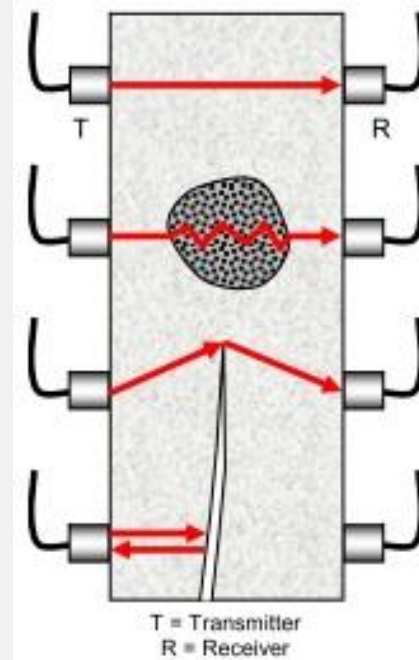
### ABSTRACT

The large marble statues can suffer serious fractures, due to the stress states originated by the weight and the shape, often thin and articulated. Fractures are often triggered by surface cracking. For this reason, it is important to assess the severity of the apparent cracks, by performing periodic nondestructive surveys. The ultrasonic method is well suited for this purpose. This paper presents a research activity finalized at improving the application of the ultrasound method to the detection of crack depth in marble elements.

In conclusion, **the ultrasonic investigation has allowed to better define the severity of the crack pattern present on the legs of the David.** The crack pattern present in the legs of David is not very worrying for the stability of the artwork, but it could become very dangerous if the statue was subject to high stresses in the dynamic field, such as those resulting from an strong earthquake.



## How does UPV work?



Proceq Pundit Lab

$$\text{Velocity} = \text{distance} / \text{TOF (time of flight)}$$

<http://germann.org/products-by-application/ultrasonic-pulse-velocity/pundit>

# The equipment



Big



54 kHz



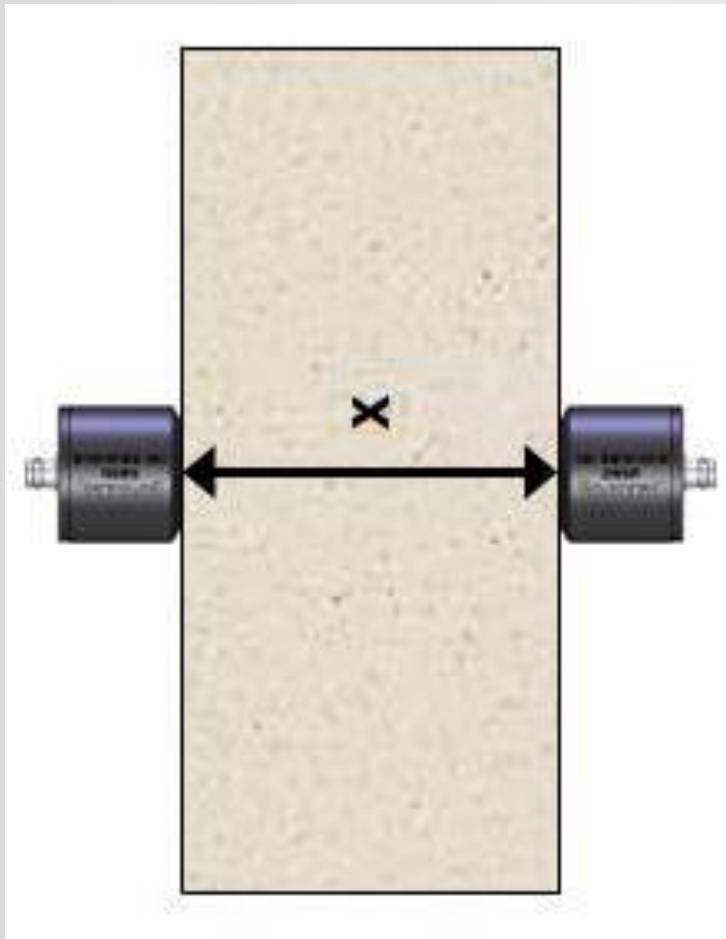
small



150 kHz



Proceq Pundit Lab



### **Direct Transmission**

The optimum configuration with maximum signal amplitude.

The most accurate method of pulse velocity determination.

The path length is measured from centre to centre of the transducers.



### **Direct Transmission:**

The optimum configuration with maximum signal amplitude.

The most accurate method of pulse velocity determination.

The path length is measured from centre to centre of the transducers.

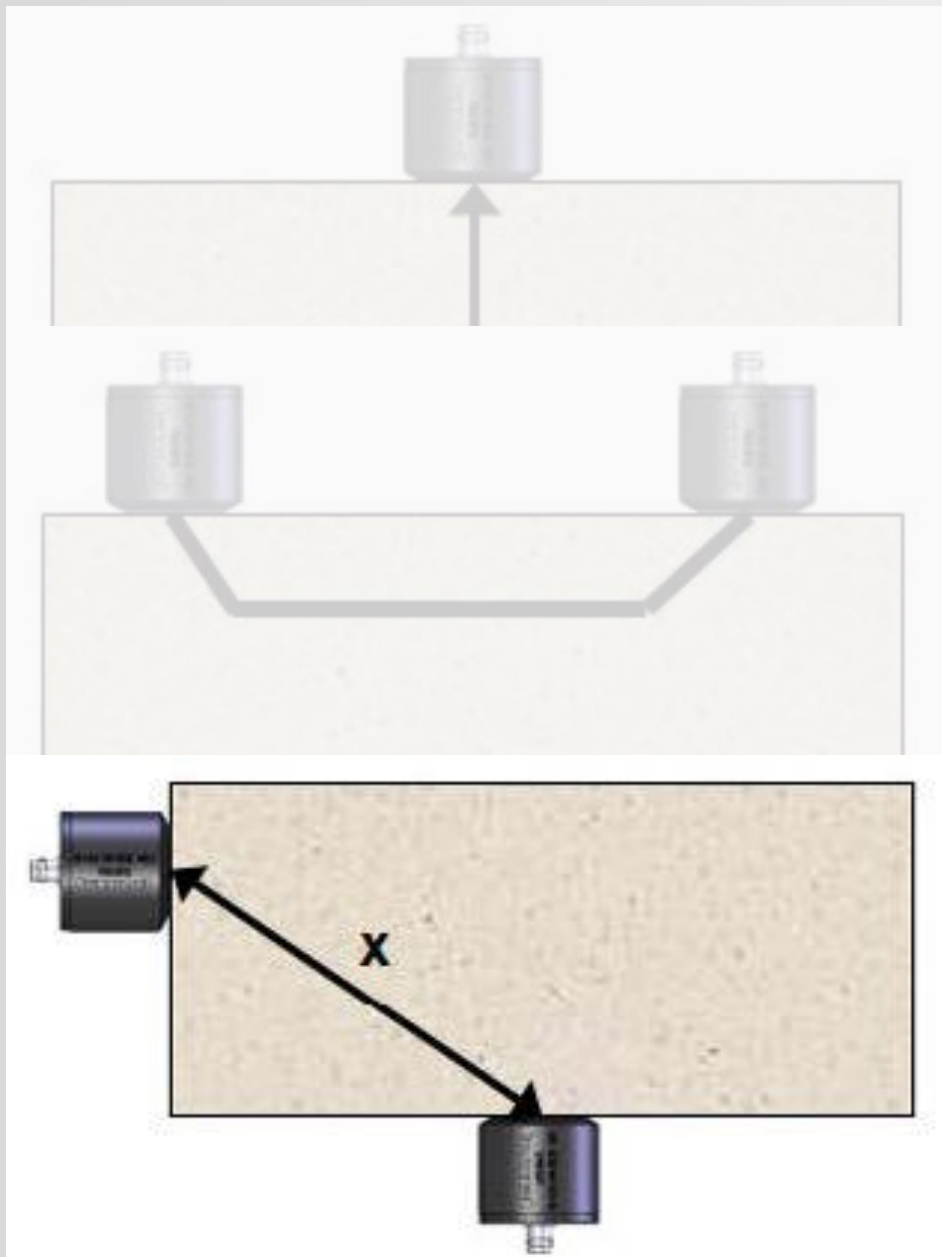
### **Indirect Transmission**

The signal amplitude is approximately 3 % of signal amplitude when compared to direct transmission. The path length may be uncertain.

The pulse velocity will be influenced by the surface material characteristics.

Where possible, comparison with a direct transmission measurement should be carried out to eliminate any uncertainty.

The distance between the transducers centres is measured.



### **Direct Transmission:**

The optimum configuration with maximum signal amplitude.  
The most accurate method of pulse velocity determination.  
The path length is measured from centre to centre of the transducers.

### **Indirect Transmission**

The signal amplitude is approximately 3 % of signal amplitude when compared to direct transmission. The path length may be uncertain. The pulse velocity will be influenced by the surface material characteristics.

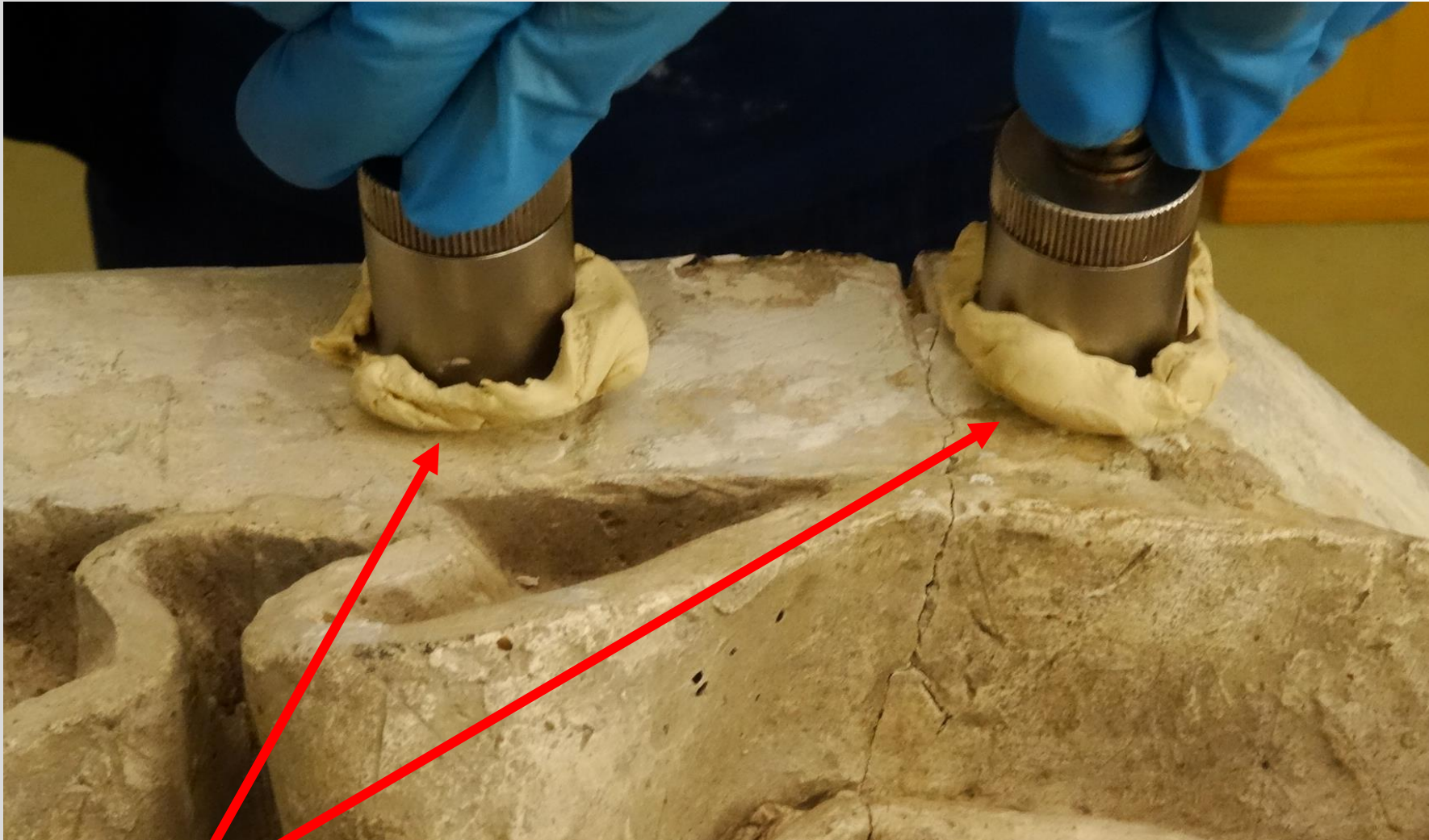
Where possible, comparison with a direct transmission measurement should be carried out to eliminate any uncertainty.

The distance between the transducers centres is measured.

### **Semi-direct Transmission**

The sensitivity is somewhere between the other two methods.  
The path length is measured from centre to centre of the transducers.

## Preparation



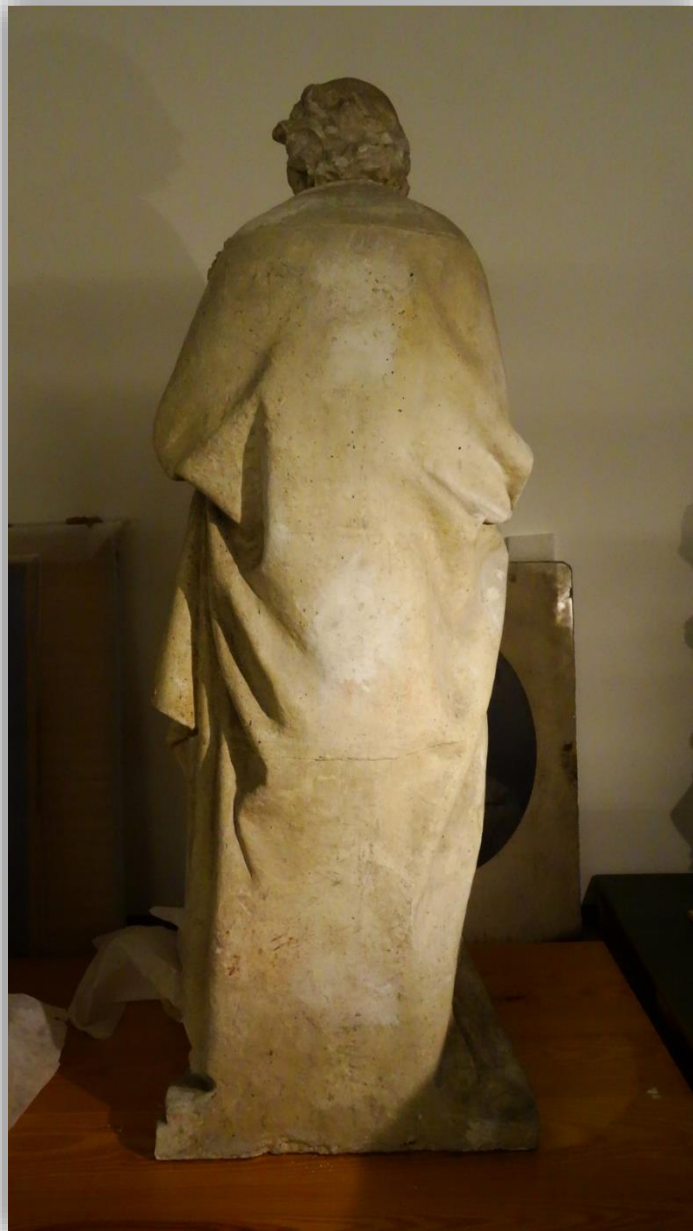
Coupling material



# São José Plaster

## Soares dos Reis - 1880





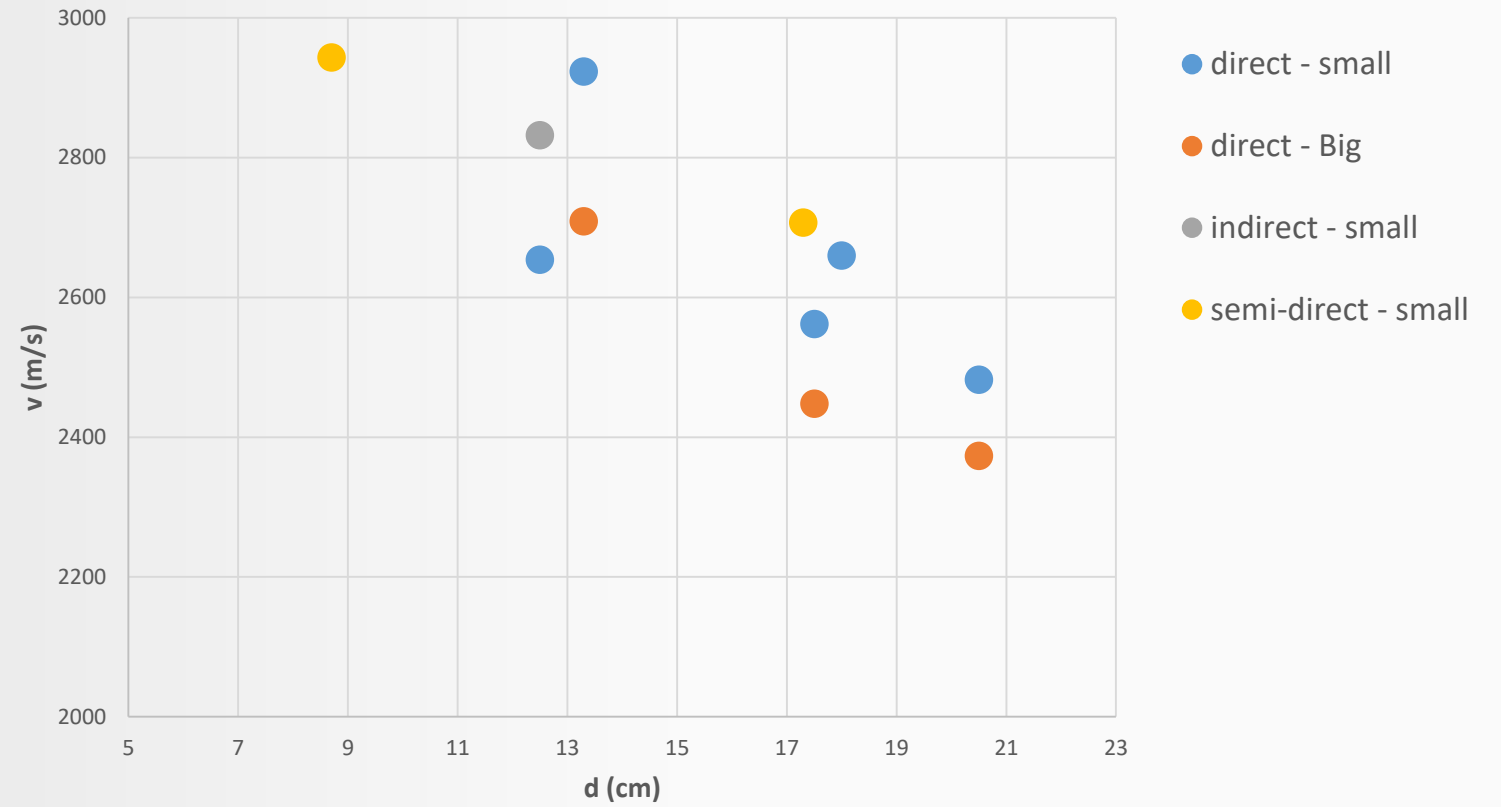
**São José**  
Soares dos Reis - 1880





# The head

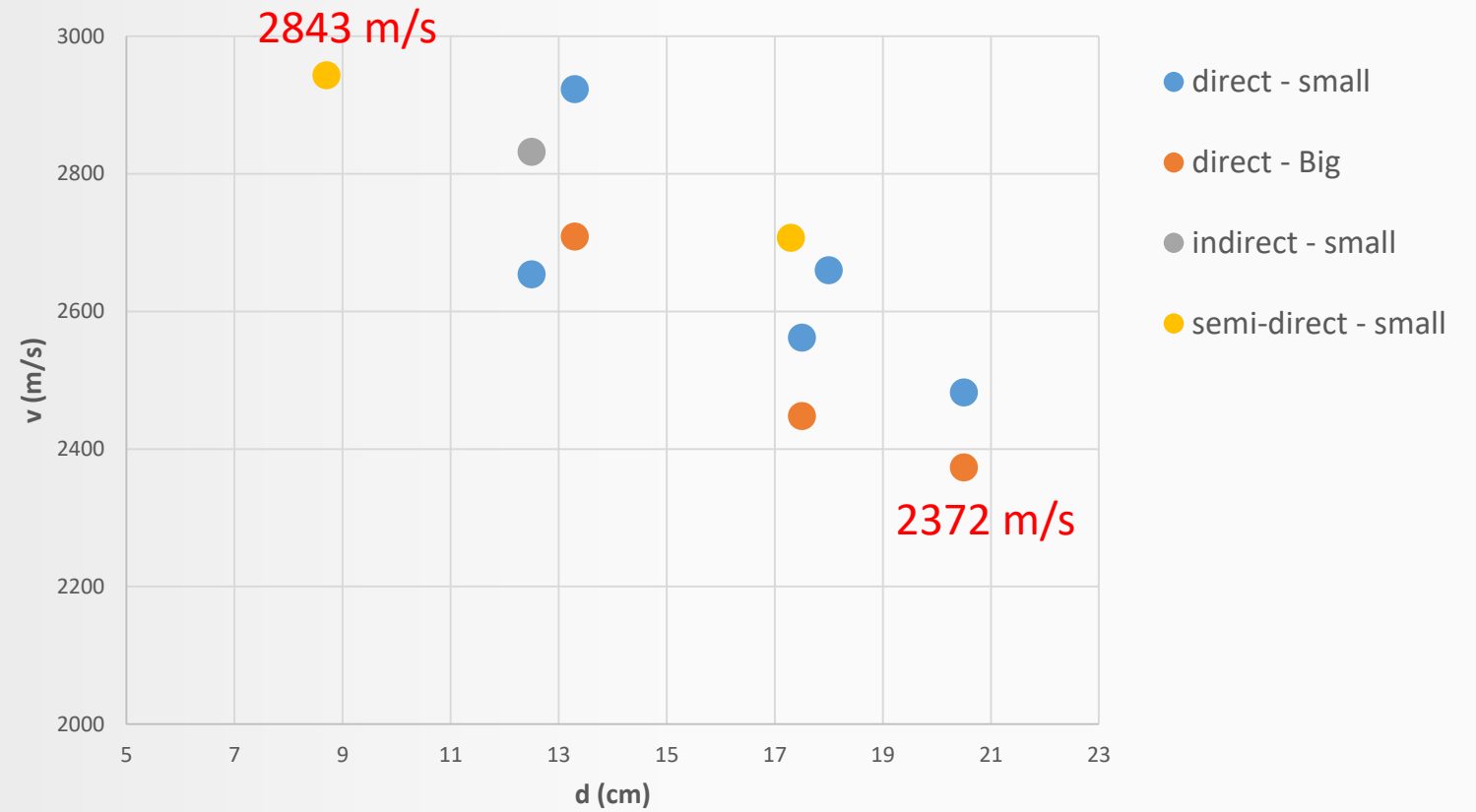
São José The head - 11 measurements





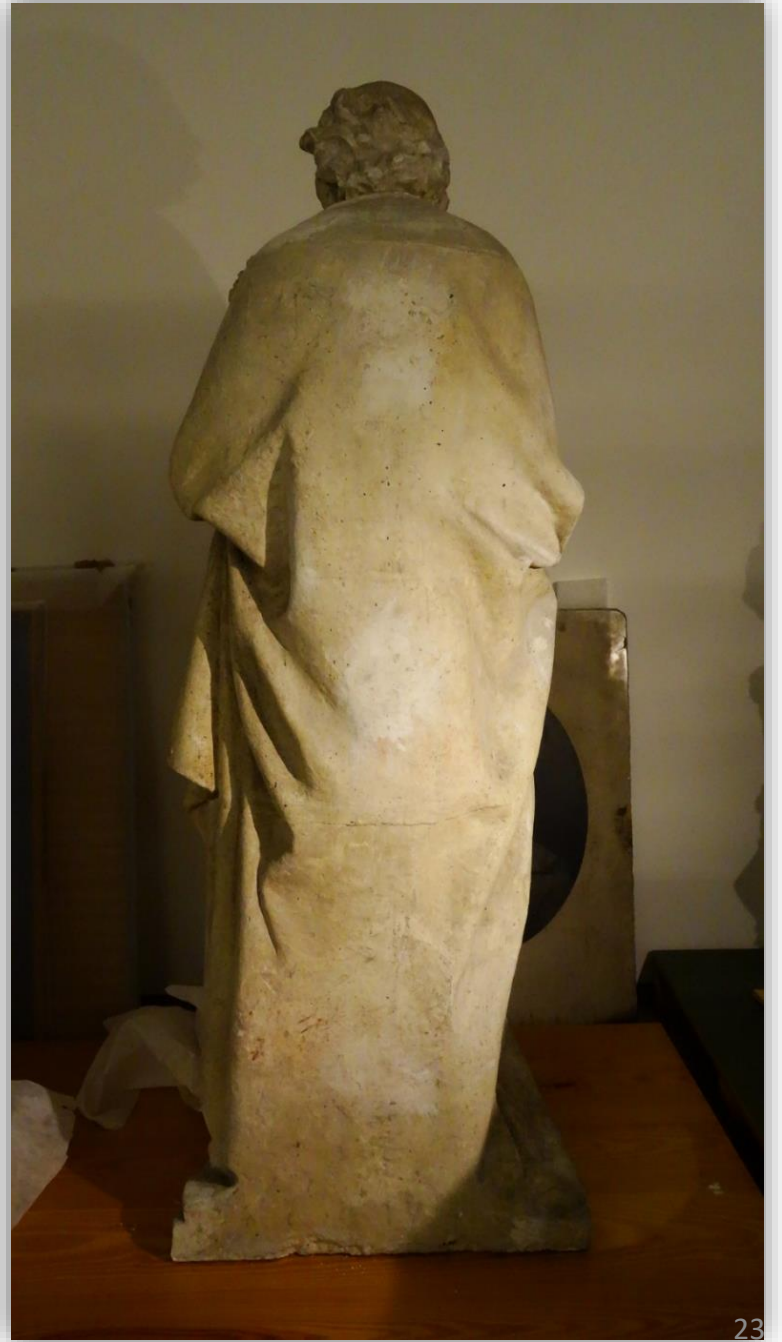
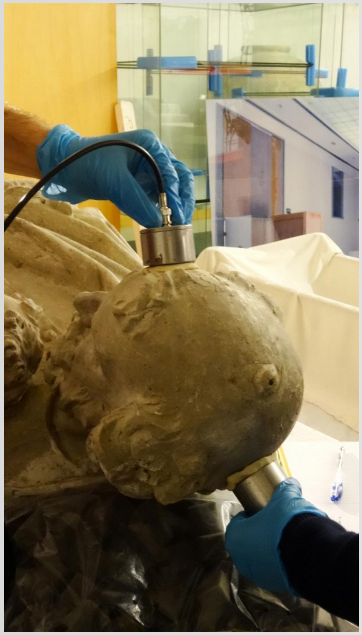
# The head

São José The head - 11 measurements

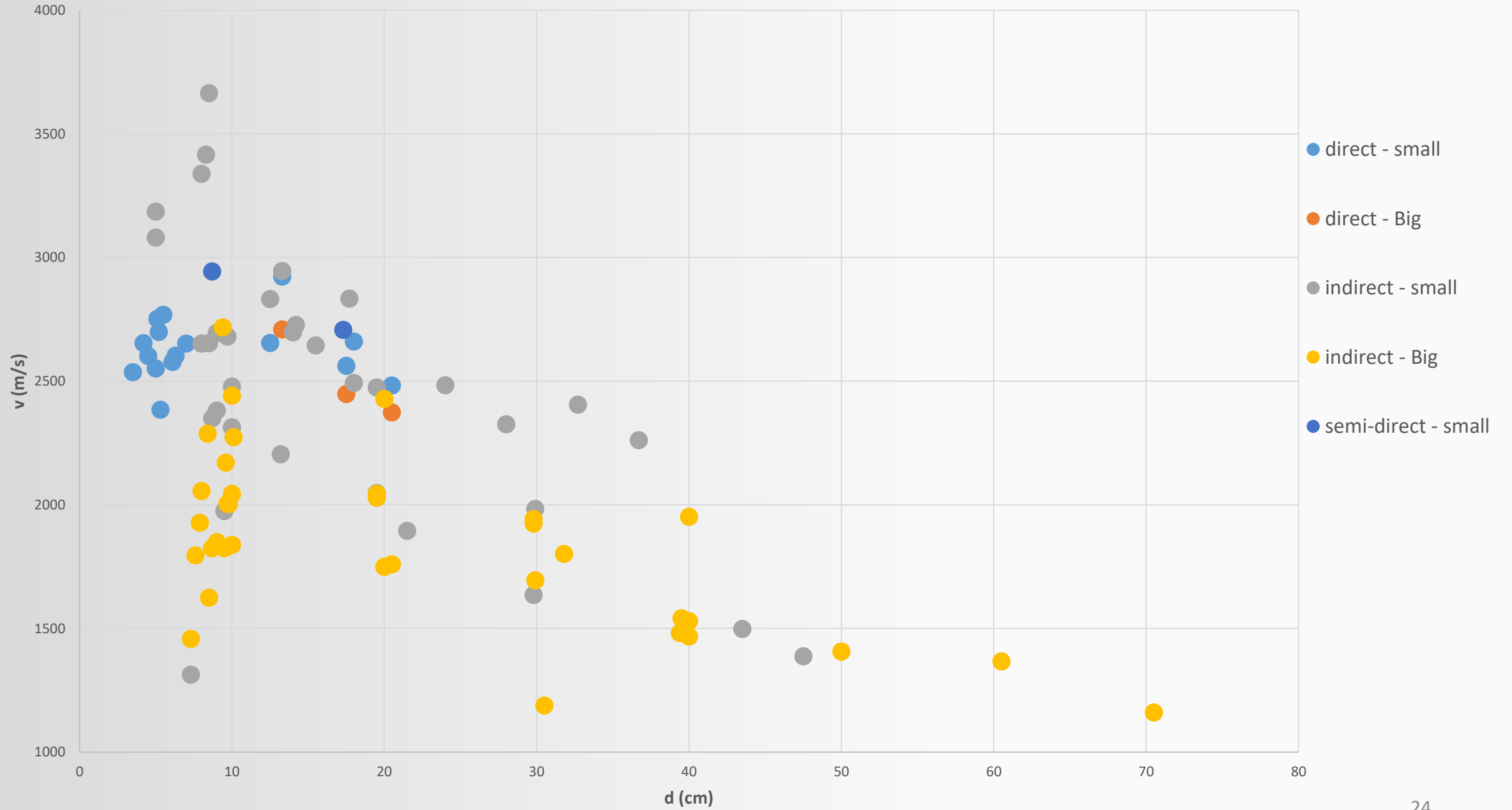






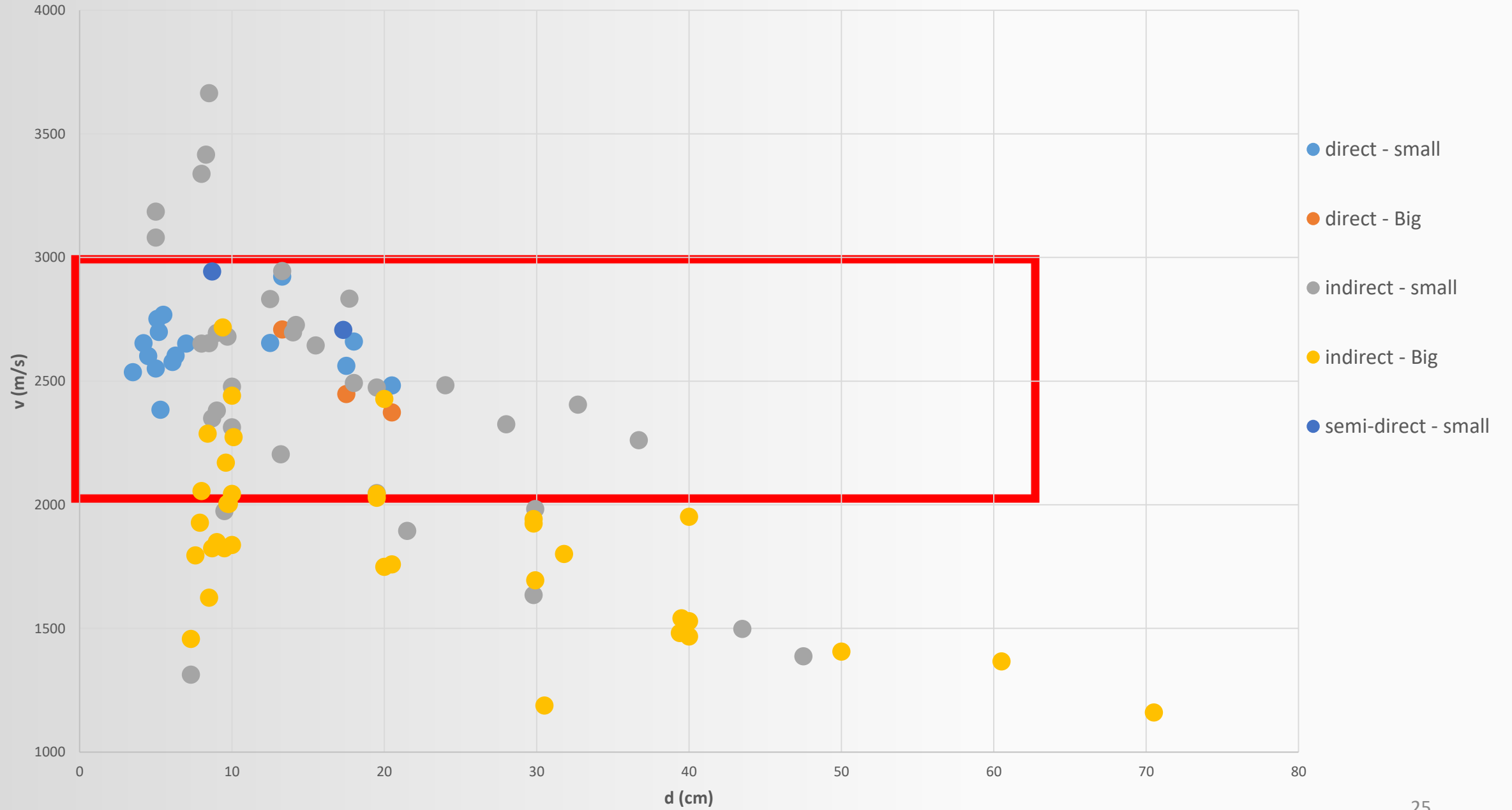


# São José all data

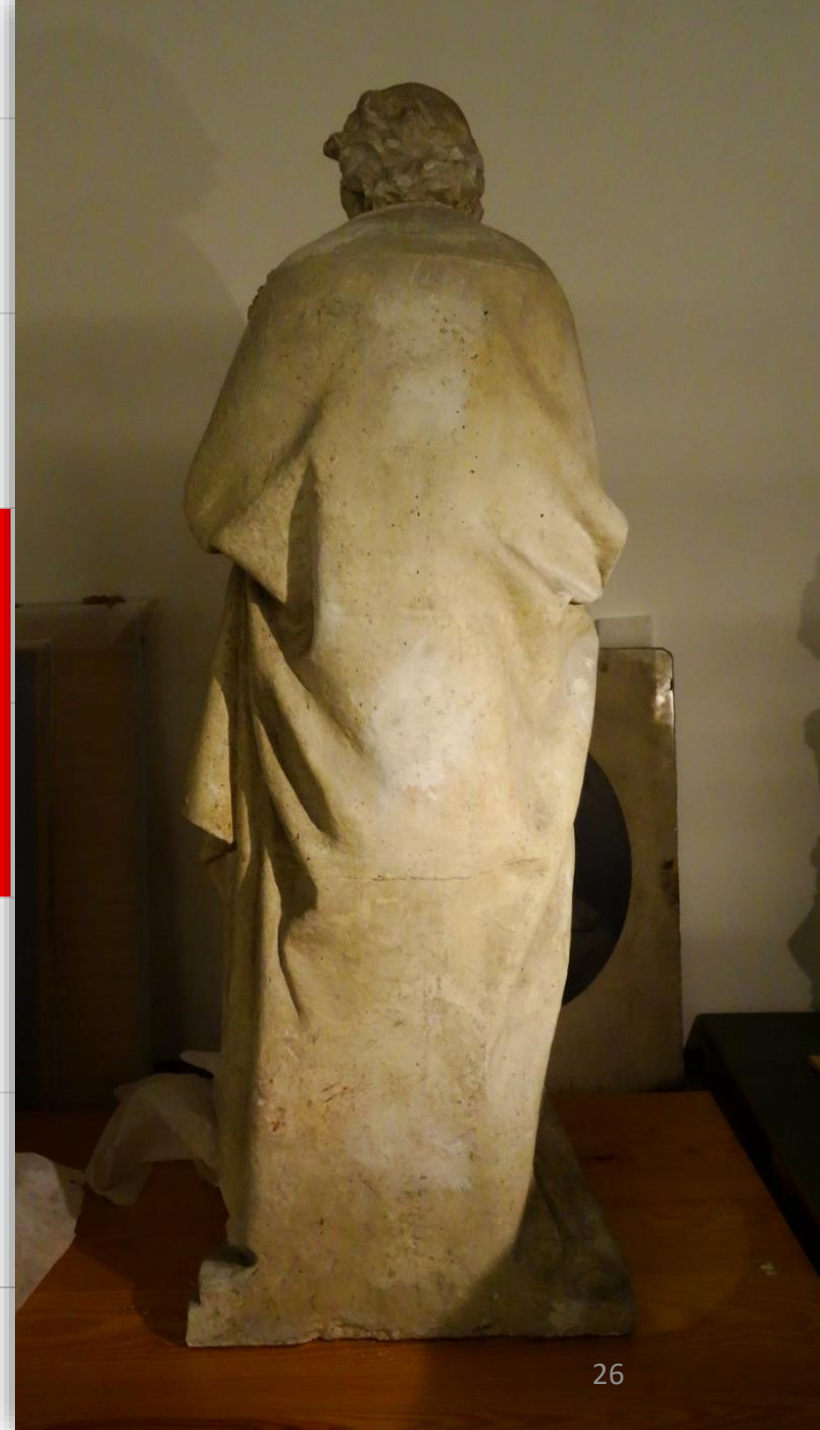
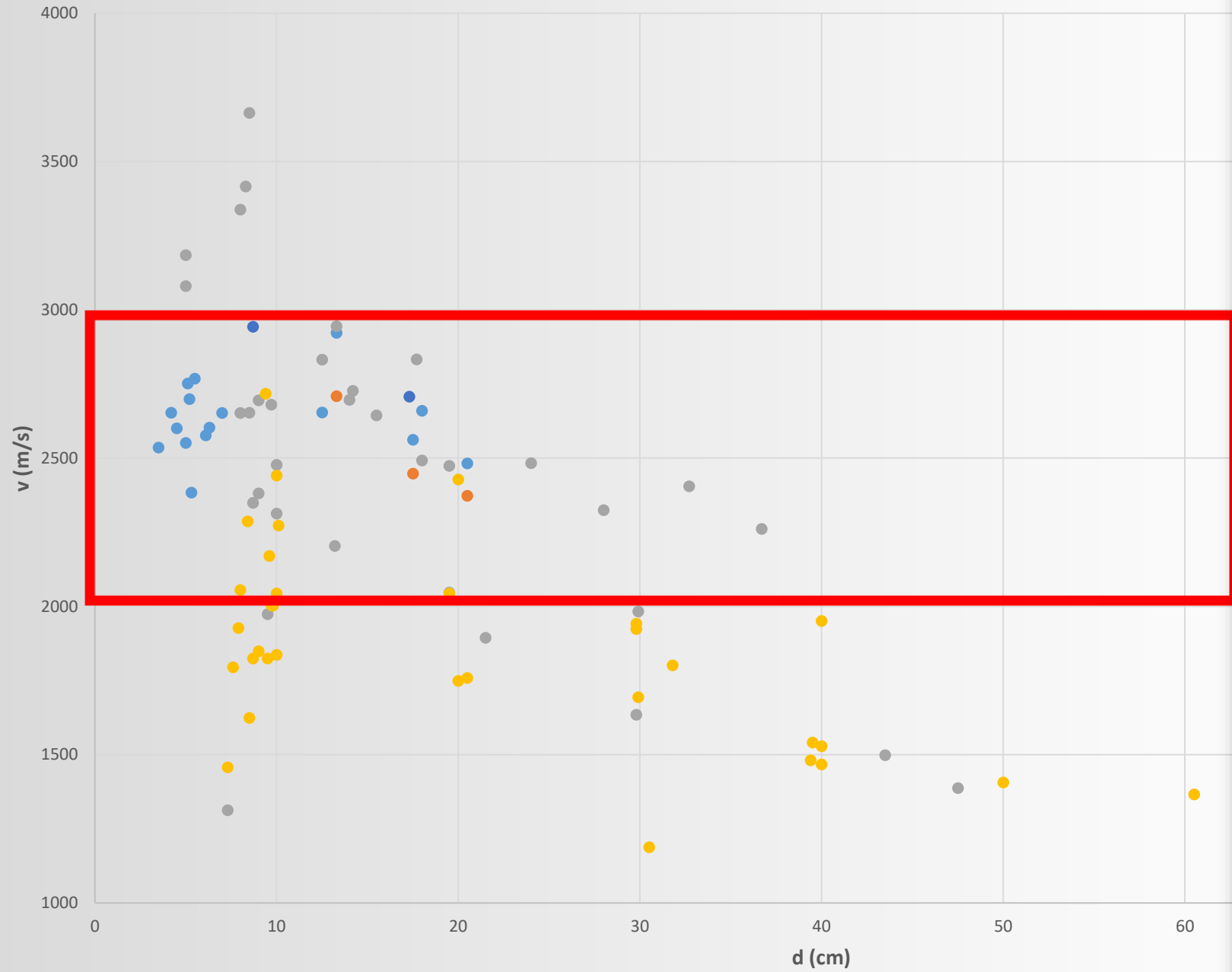




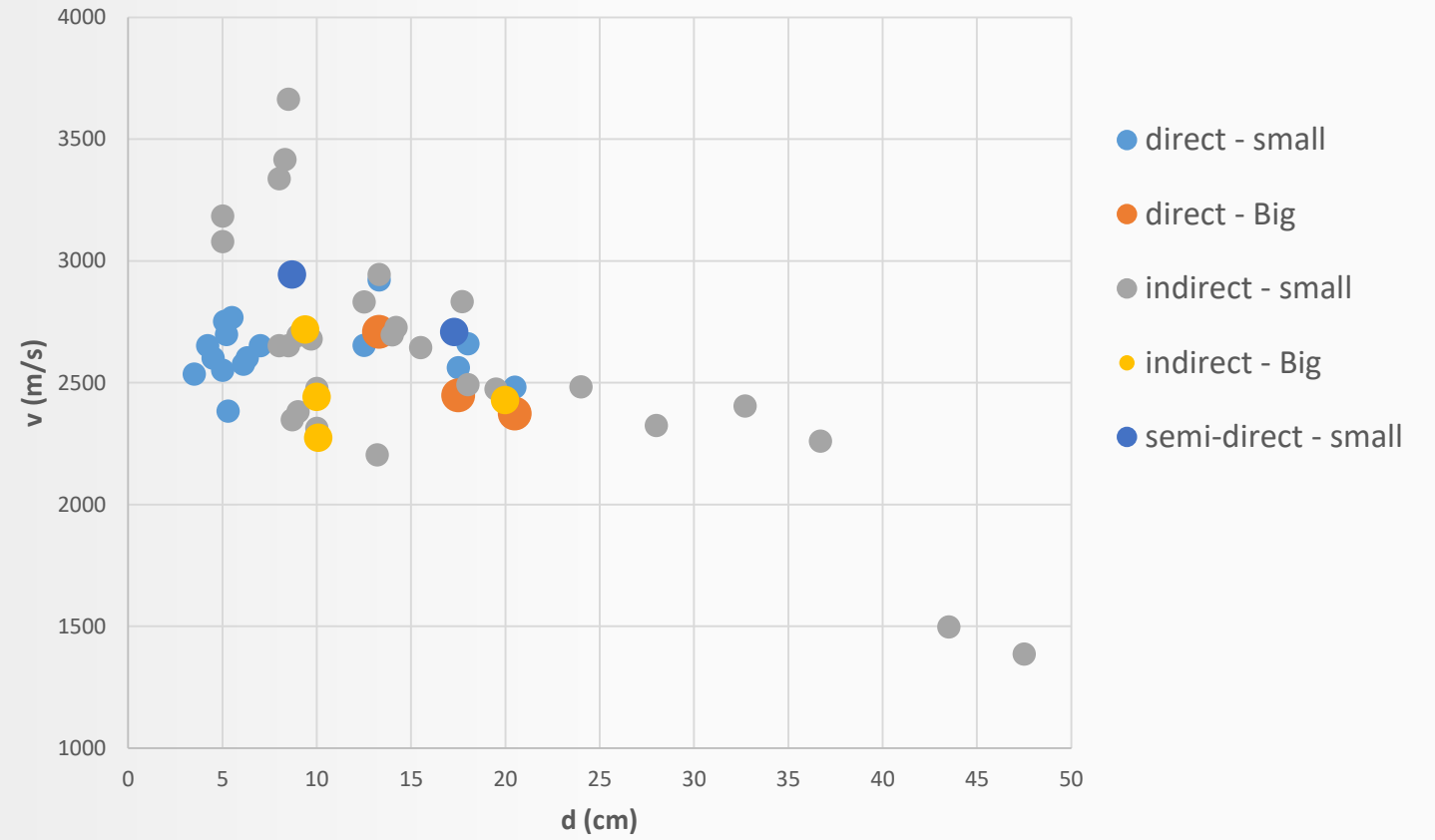
# São José all data



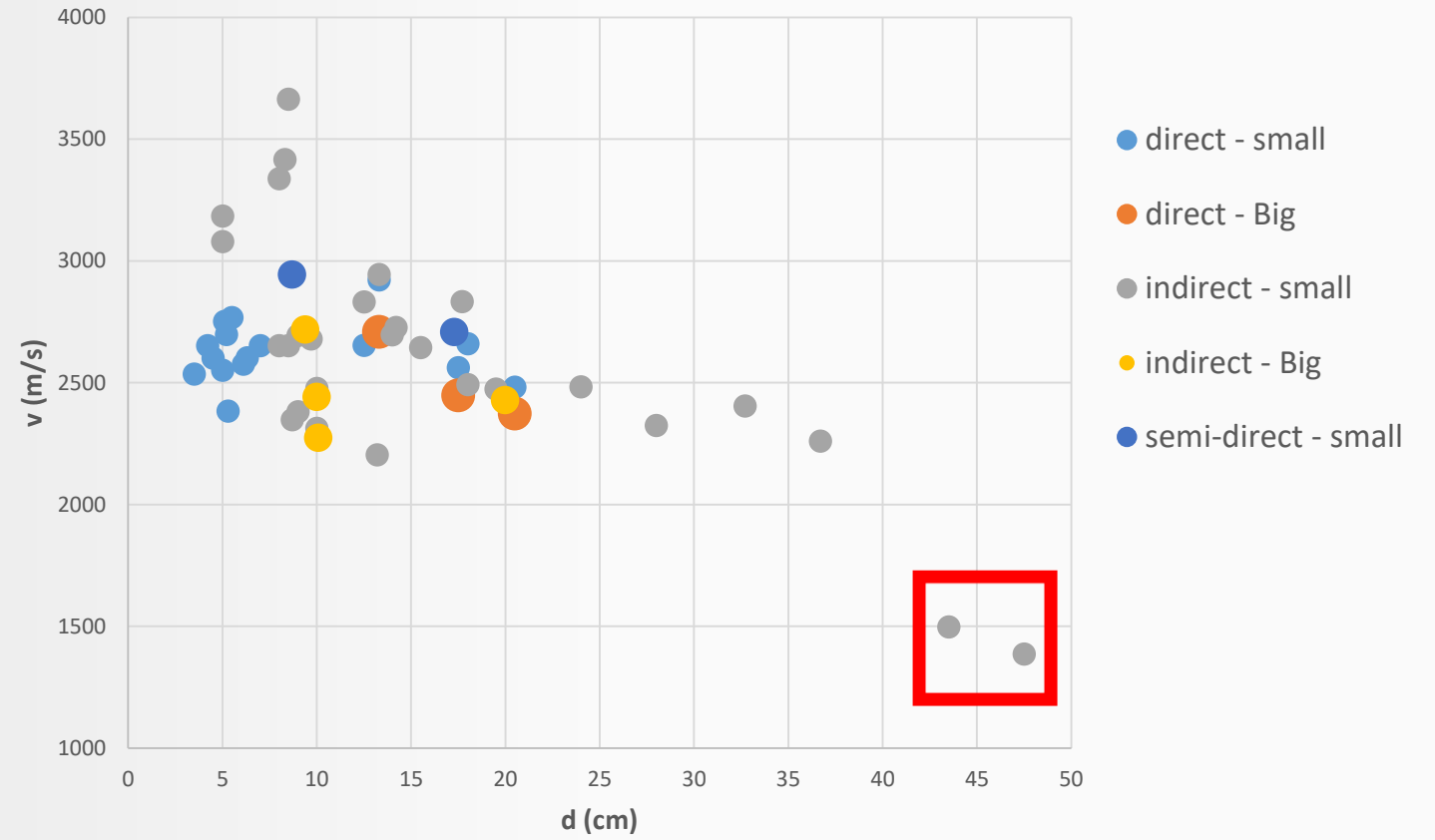
São José all data



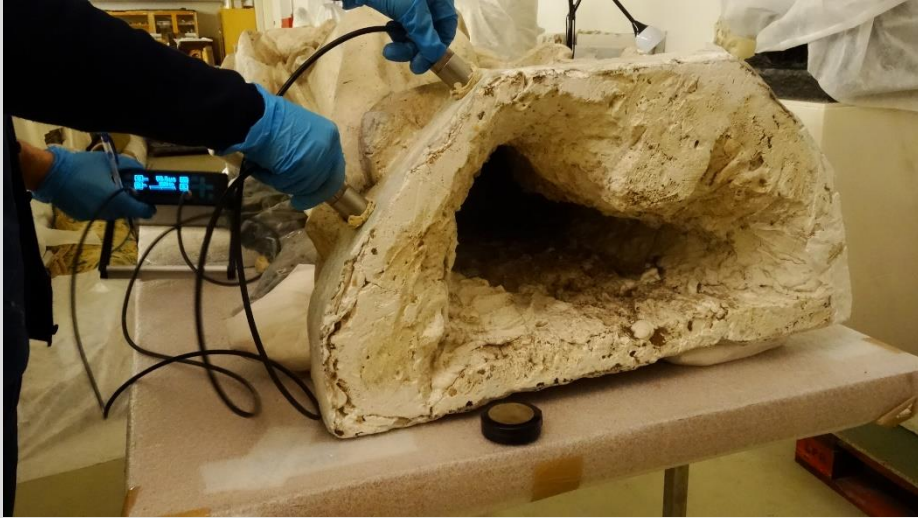
Removed data from repaired areas on the back



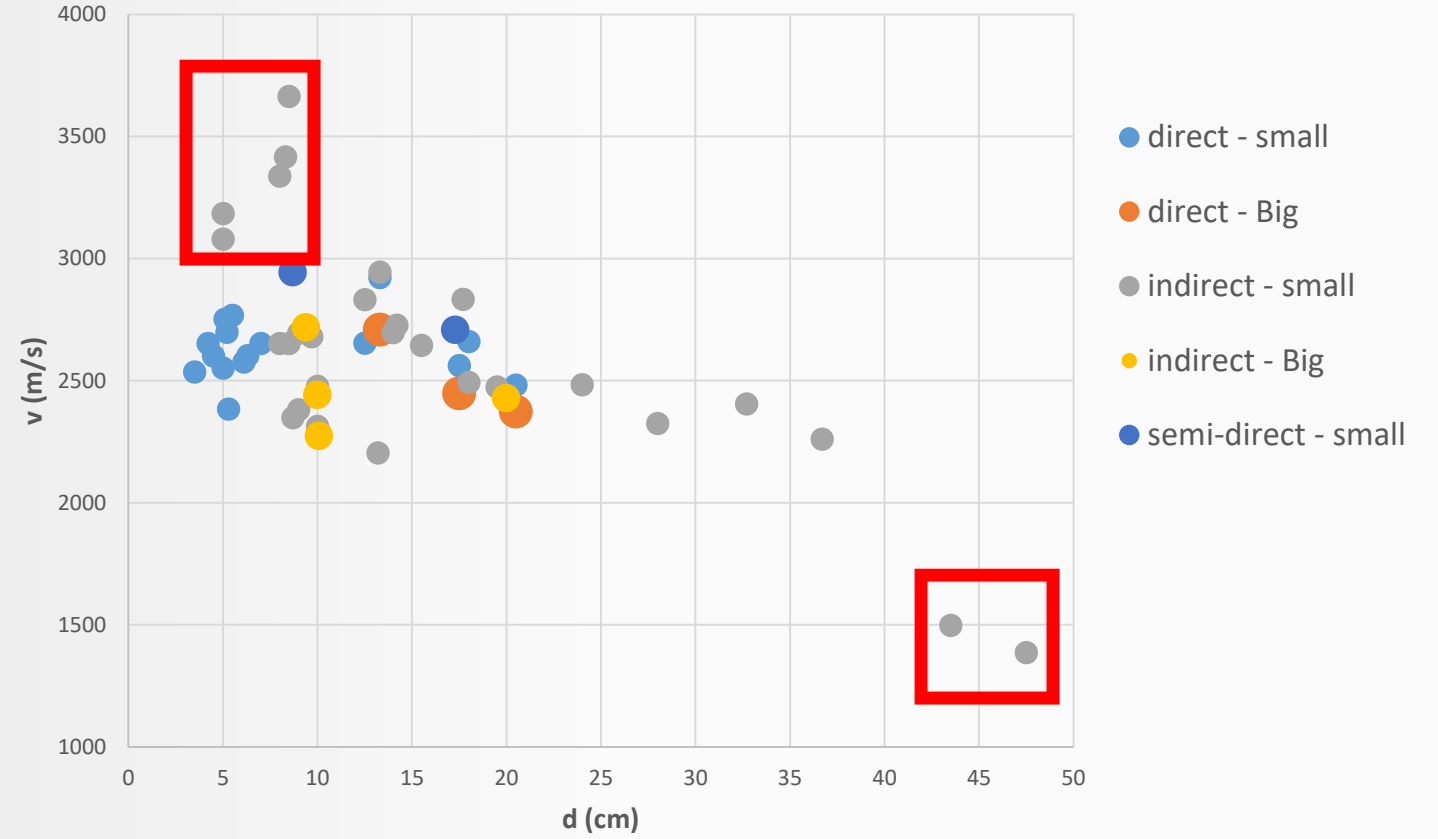
Removed data from repaired areas on the back







Removed data from repaired areas on the back





# São José Plaster

## Soares dos Reis - 1880

- The head is in very good condition.
- The frontal clothing, where was possible to measure, showed to be in good condition, with some repaired spots.
- The base and the back present several damages, repaired with some sort of cement.

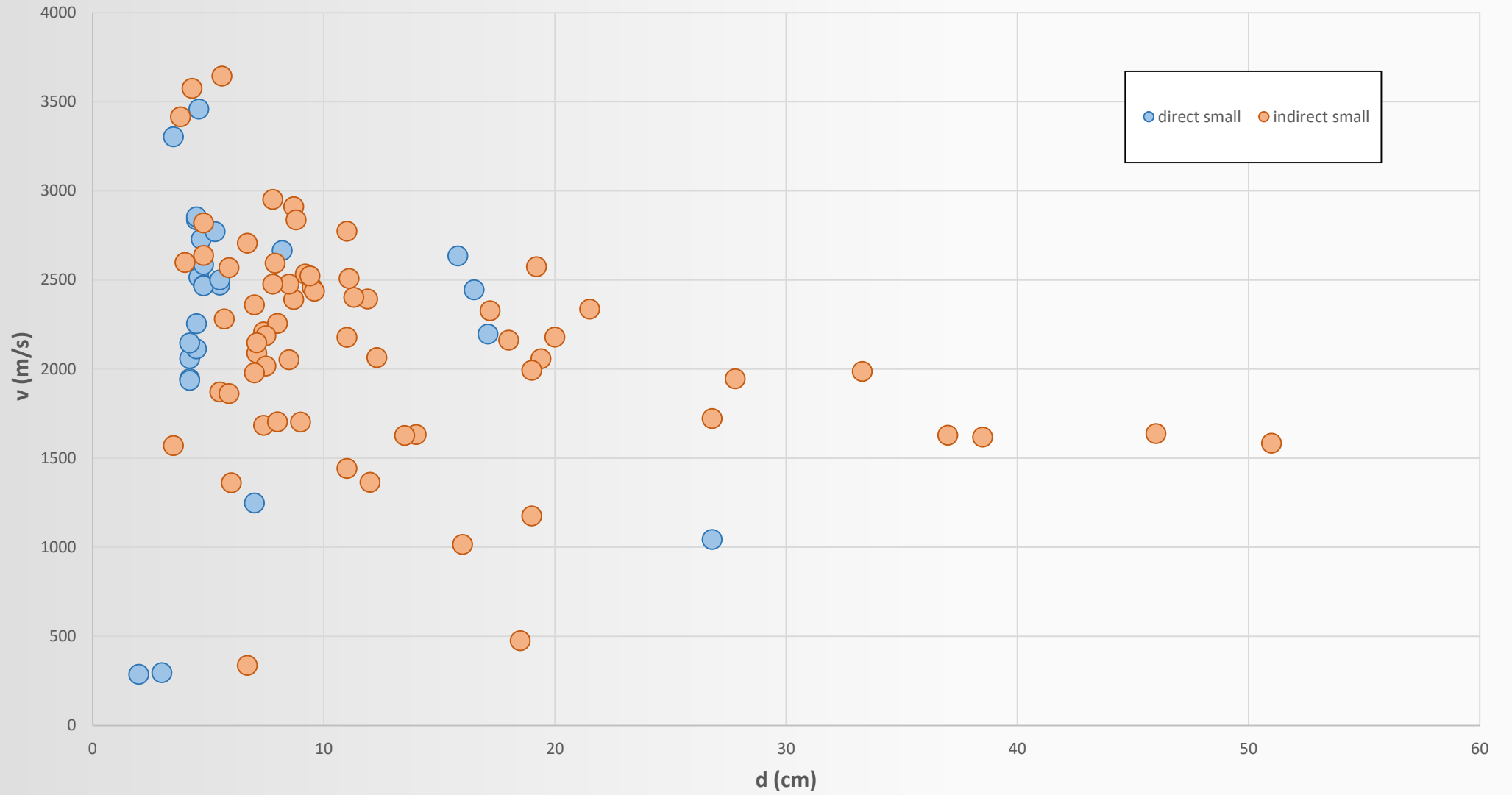
# São Joaquim Plaster

## Soares dos Reis - 1880

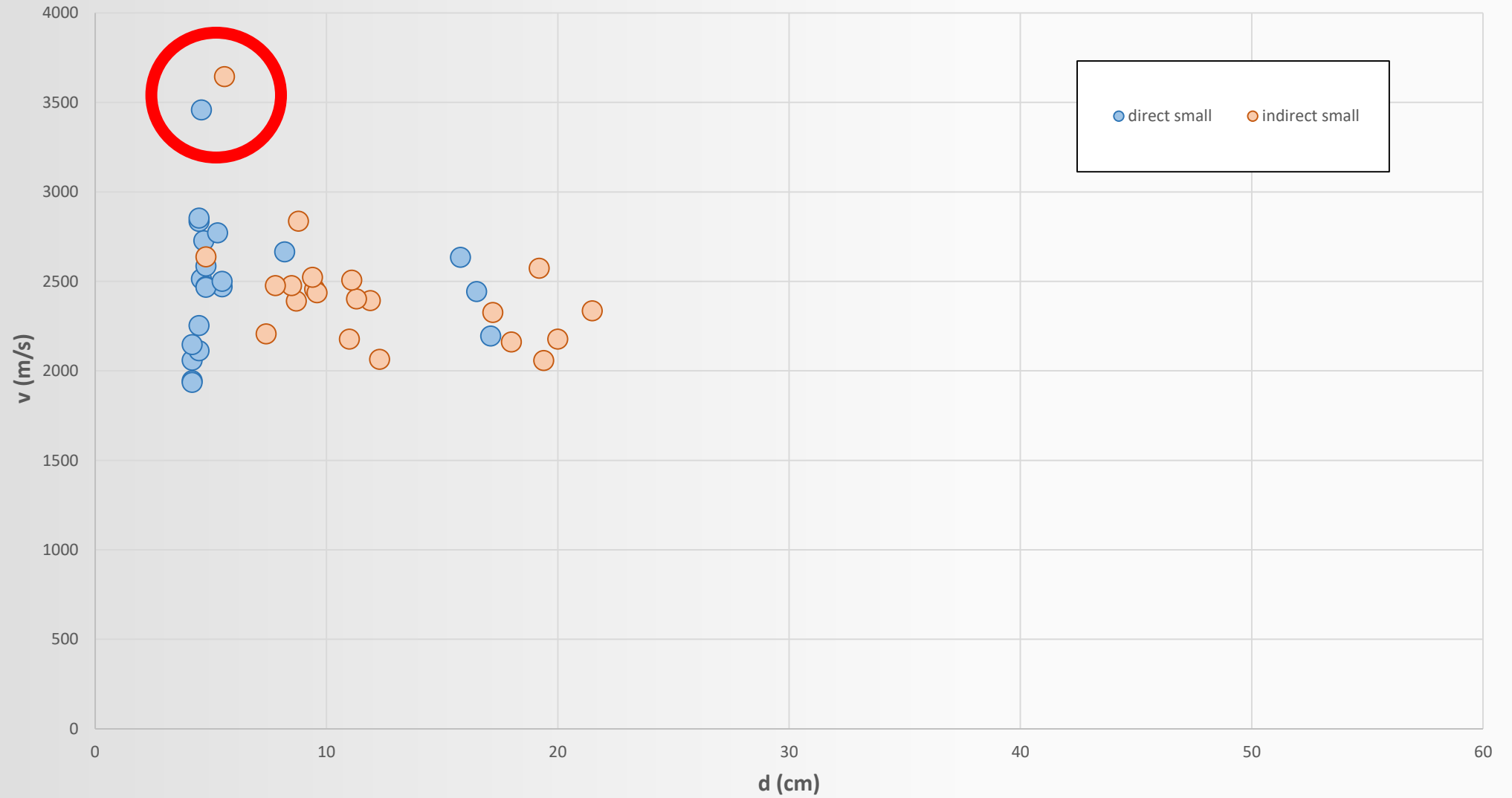




São Joaquim all data



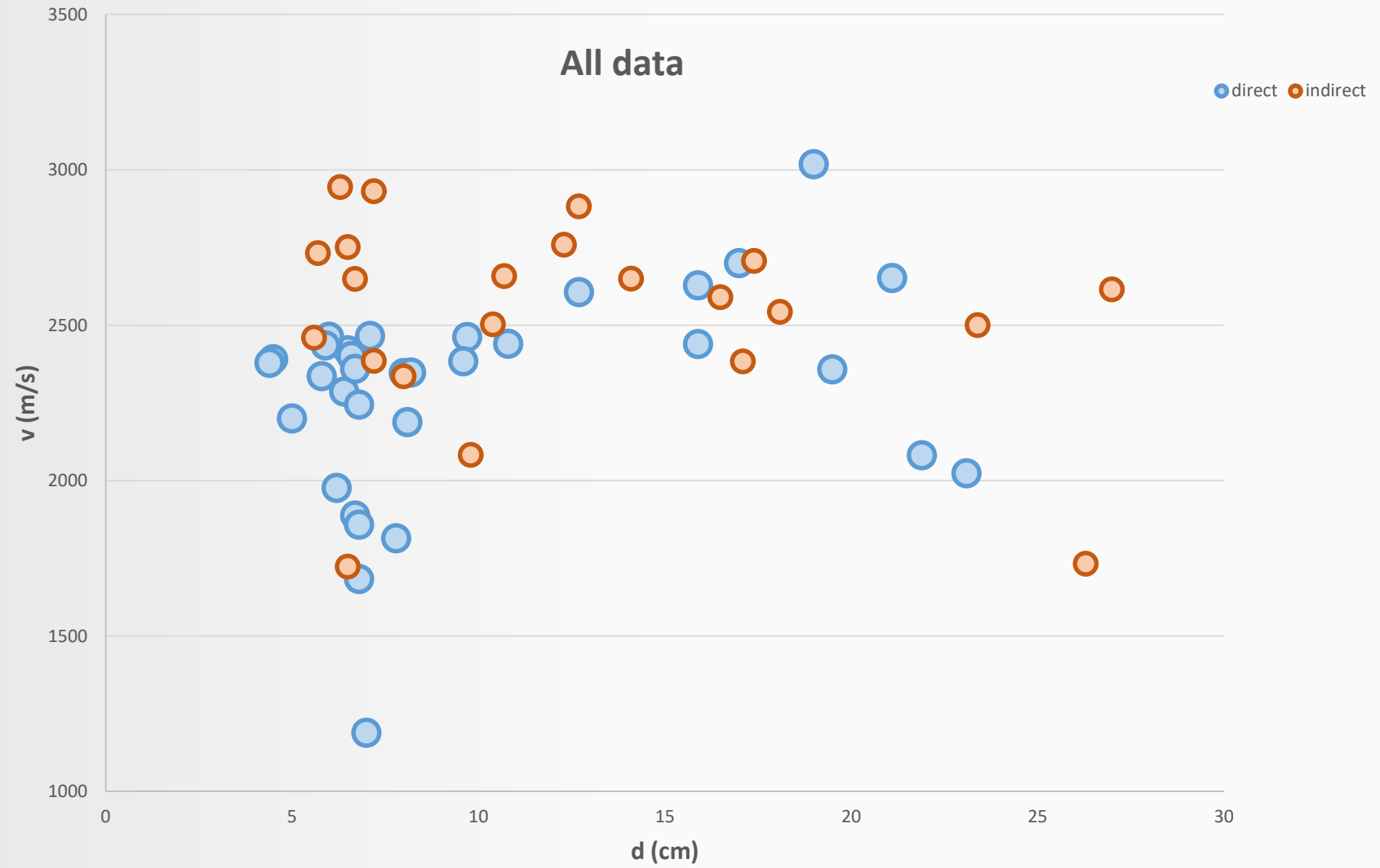
### São Joaquim removed data from repaired areas

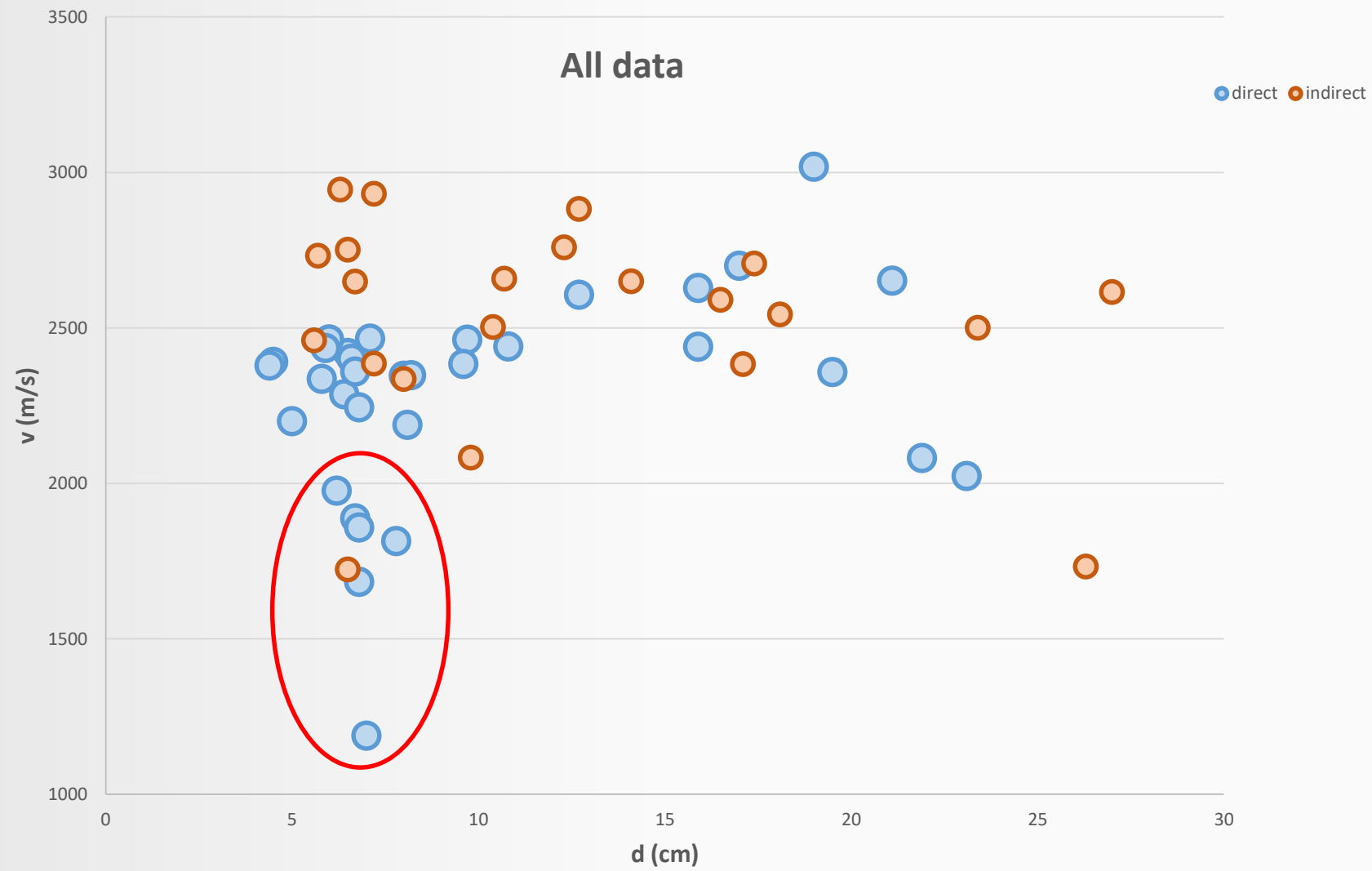










# **Narciso**      Plaster

## **Soares dos Reis - 1881**





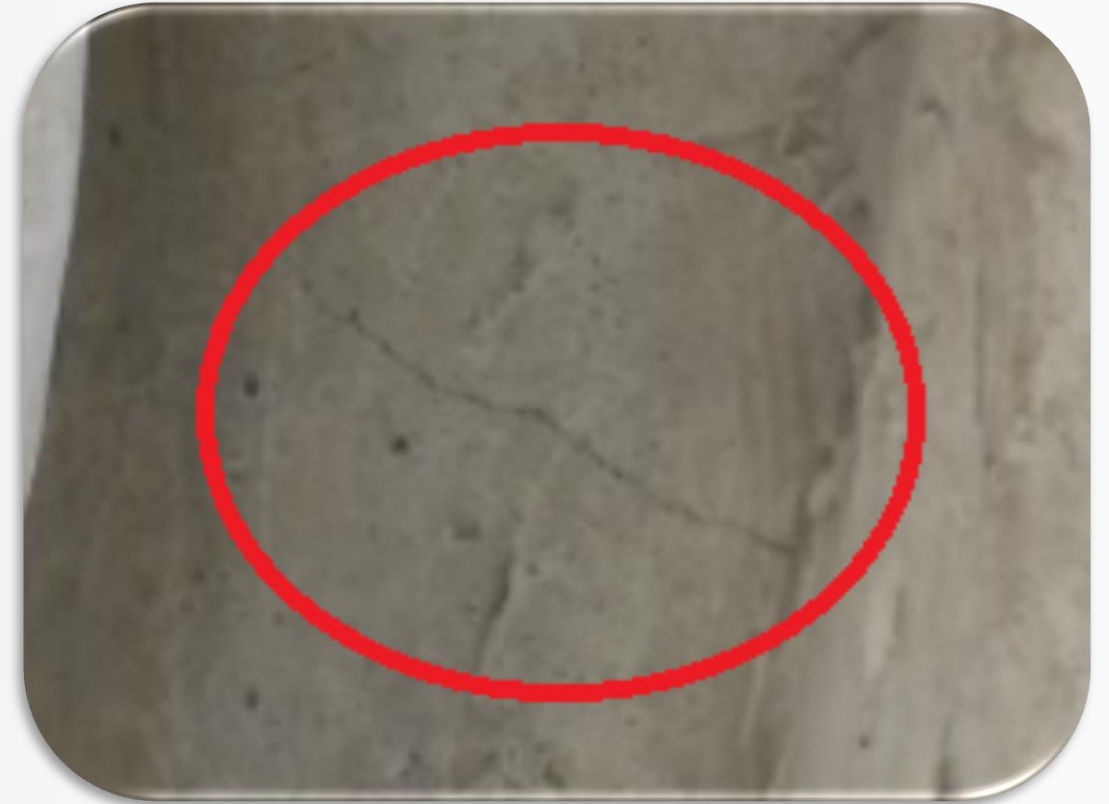
# Some of outstanding data

#31	#32	#33	#34	#35	#36
					
2187 (m/s)	1814 (m/s)	923-1128 (m/s)	1887-2359 (m/s)	1683-1858 (m/s)	1976 (m/s)

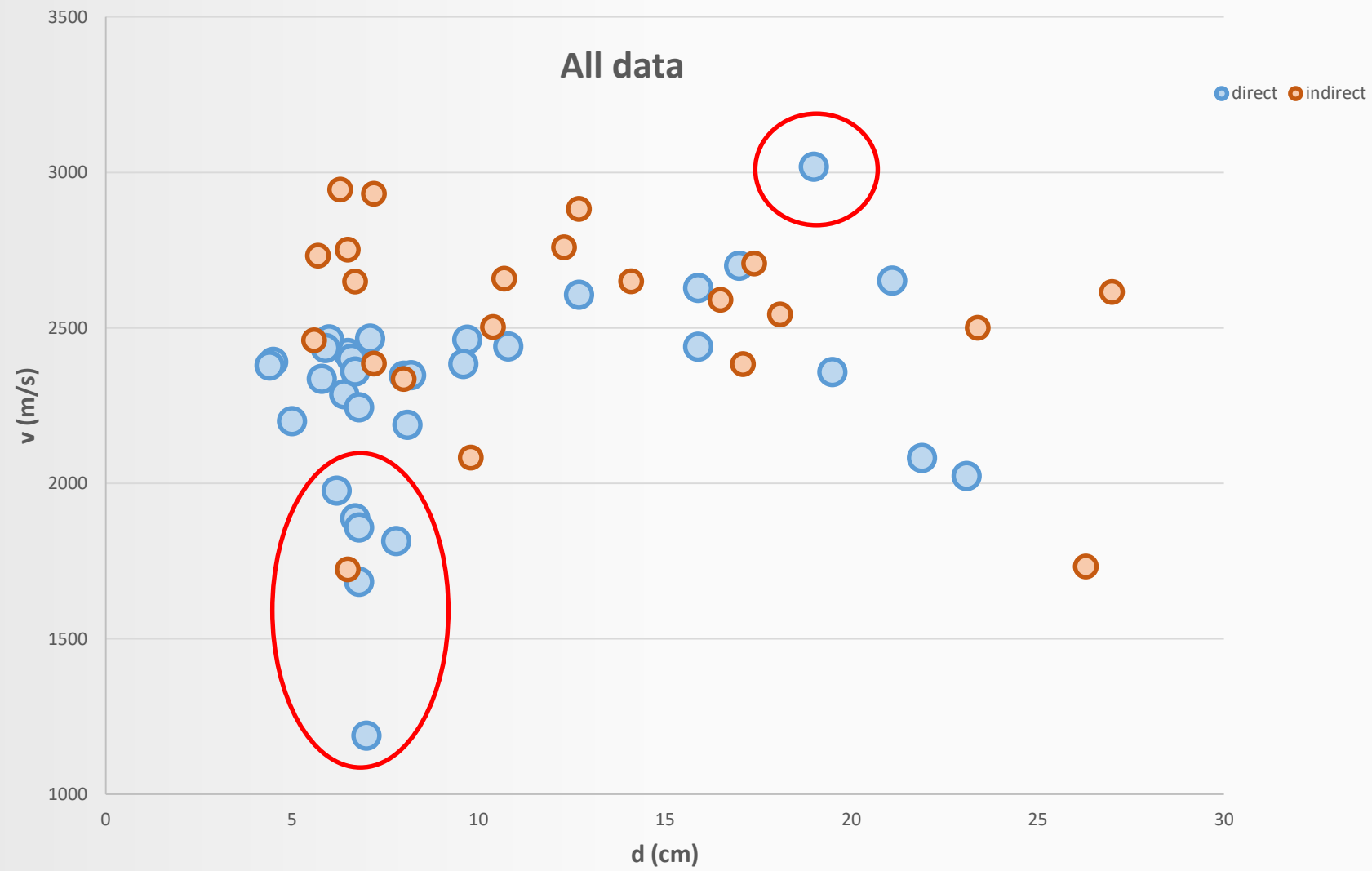
- The data collected in direct measurements on the right leg were troublesome from the beginning:
- the various TOF recorded for each position were not consistent, showing dispersion, making us collect more data with no better consistency;
  - the velocity calculated for the TOF extremes obtained in each measure is well below the usual values.

#32

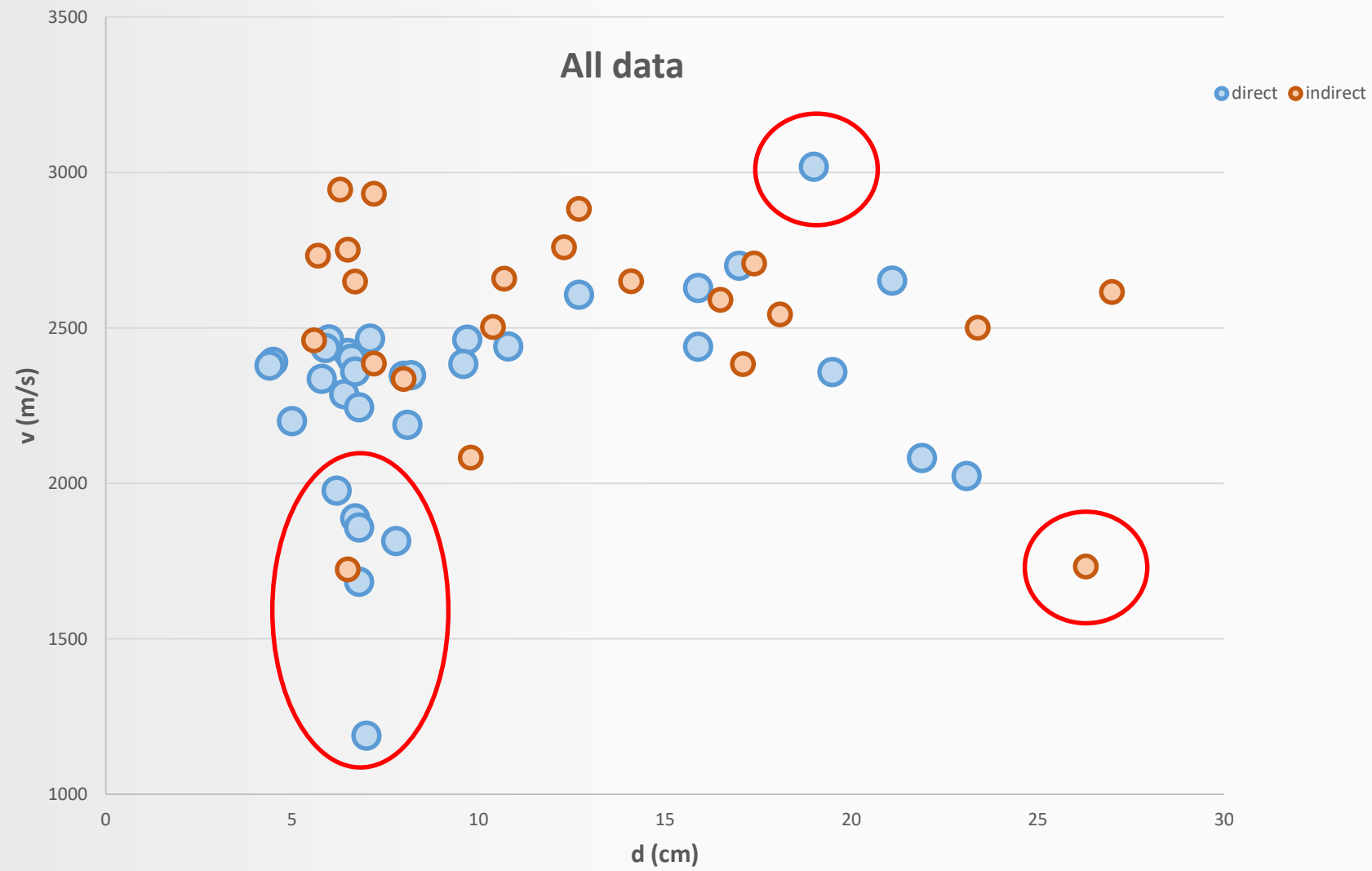
#49

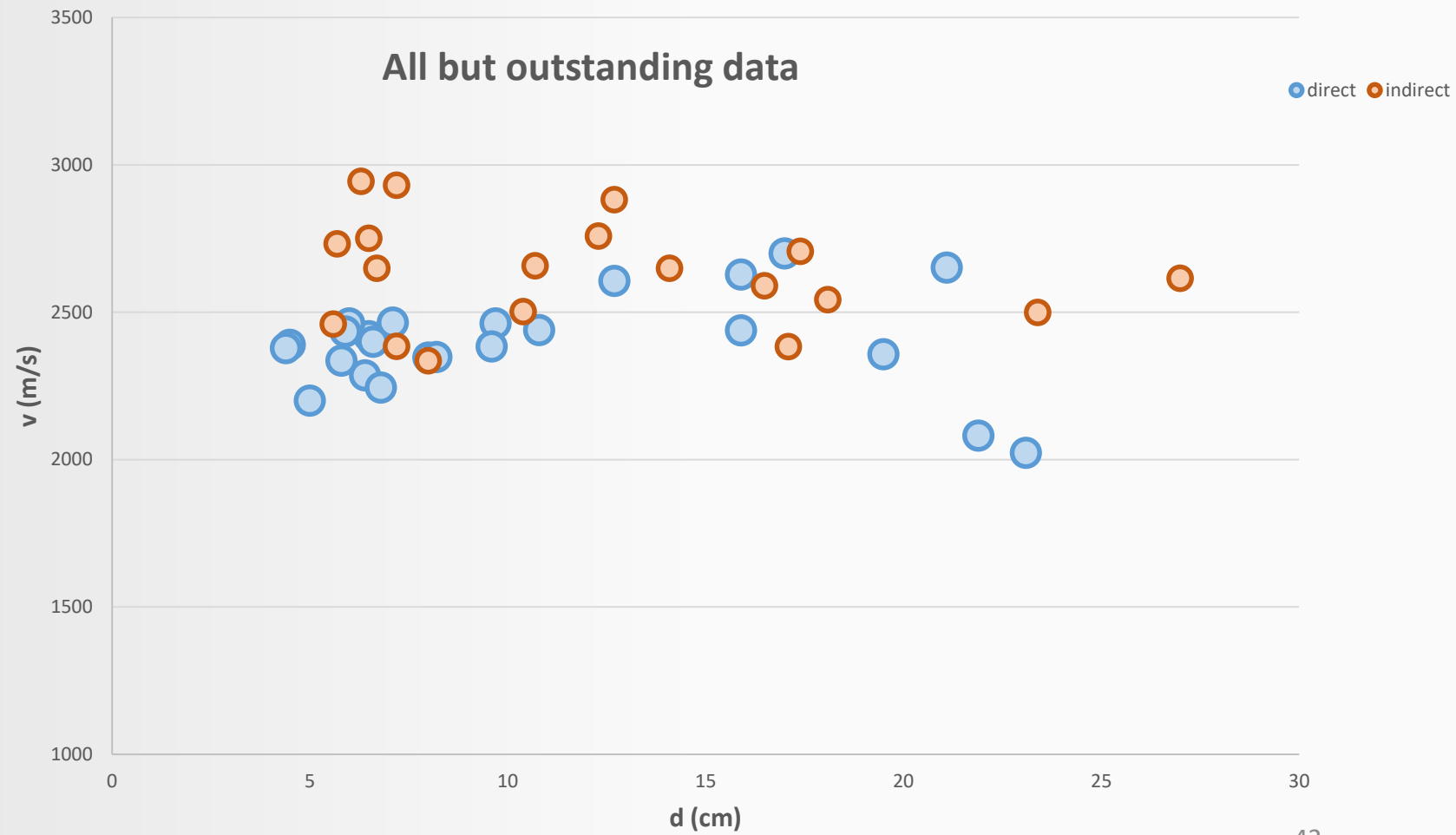


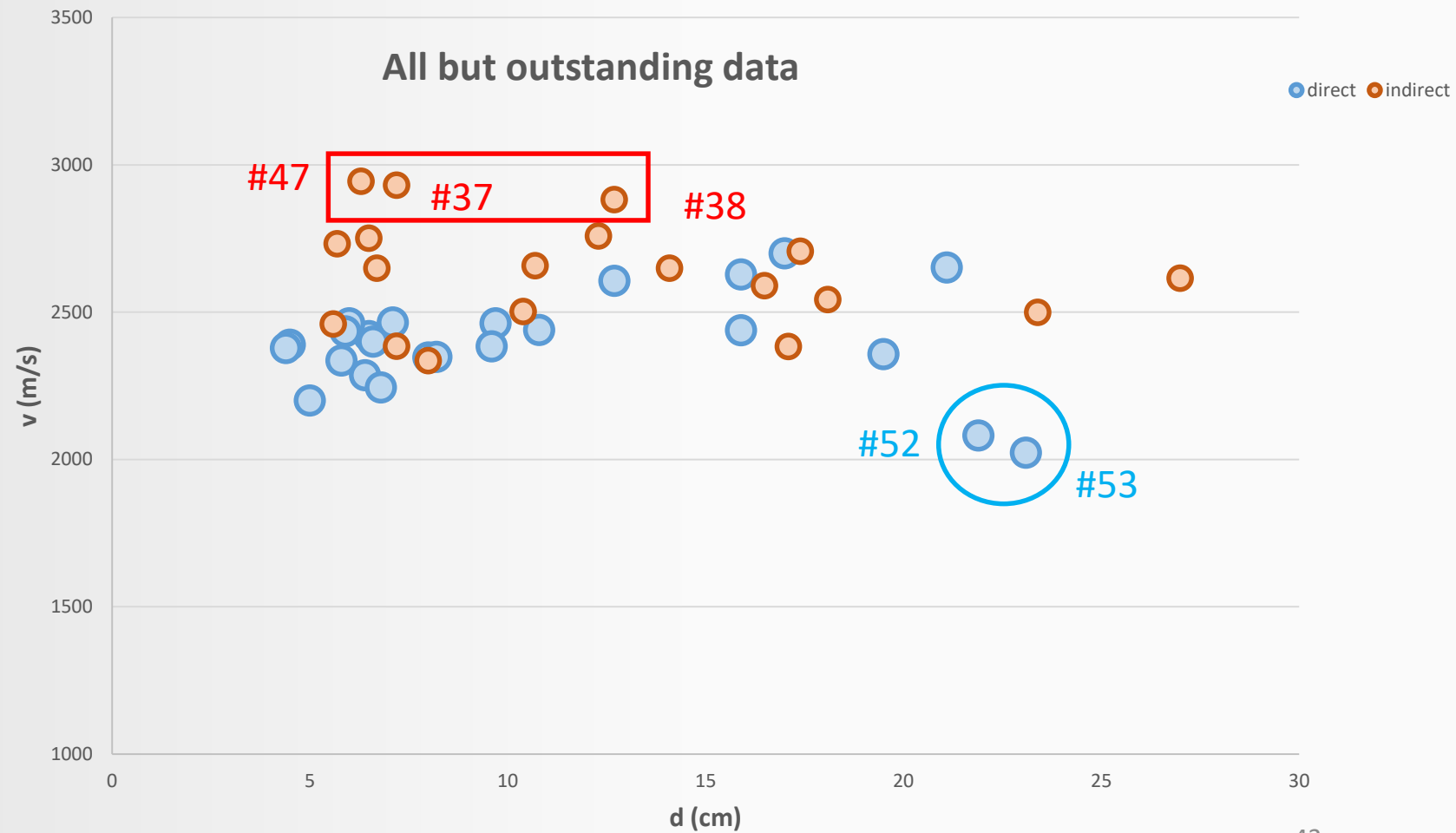
An indirect measurement at the interior of the right thigh (#49) gave a high TOF and a visual inspection of the surface has shown a thin but extensive crack.













# Narciso

Plaster

## Soares dos Reis - 1881

There seems to be a problem in the right leg:

- lower values of velocity are associated to regions where cracks can be seen;
- higher values of velocity suggest that there has been an earlier intervention.

# Conclusion

- This preliminary approach to use UPV on plaster sculptures has shown to be useful:
  - the UPV portable equipment can be easily adapted from concrete and rock experiments;
  - ordinary groom stick, of common use in cleaning artworks, is just perfect as a coupling material between the transducers and the objects to study;
  - The data acquisition of TOF and their distribution are good indicators of the quality and integrity of the piece under study.
- Some anomalous results can be interpreted straightforward, but others need further attention using conventional techniques to detect the origin of the abnormality and, thus, argue in favour of the UPV utility in the conservation assessment of plaster sculptures.



**Thank you for your attention**

**A. Mário Almeida**

Departamento de Física

Universidade do Minho

coimbra@fisica.uminho.pt

