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Contemporary difficulties and challenges for the implementation and development of compressed earth block building technology in Argentina

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ABSTRACT

The construction with compressed earth blocks (CEB) has provoked special worldwide interest in recent decades. In Argentina it has considerable experiences due to technical research, its use in public works and the development of some manufacturing units at different scales. The particular interest of its technology transfer to low income population sectors has been central and defines the social profile with which it has been implemented in the last time. However, its contemporary development has a low territorial impact due to the fact that problems are observed that hinder the implementation, dissemination, economic support of the manufacture and CEB commercialisation and the transfer of this technology. The aim of this article is to characterize and discuss the nature of the problems that hinder further development of CEB construction technology in Argentina. Local scientific production was analysed and the agents involved in the CEB production process were identified, who were surveyed and interviewed asking their assessment of the problems that affect the development of this technology today. The results show that the technical aspects involved in the CEB manufacturing stage are the ones that have received the most attention so far, much of the current difficulties to continue with its development are focused on the implementation, dissemination, and economic sustainability of the CEB manufacturing and commercialisation and the transfer of this technology. The lack of a specific regulatory framework for this technology is transversal to these problems mentioned. With regard to the scientific field, these issues need to be incorporated into research agendas, at least at the local level.

1. Introduction

1.1. Background

In the last decades, the use of earth as construction material has experimented a renewed interest and encouragement due, mainly, to the lower environmental impact produced by its employment throughout its life cycle [1–4]; likewise, the economic issue

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complements this interest, due to the lower relative costs compared to other construction materials. Added to the latter, earth is considered an abundant and reusable natural resource [5,6]. These aspects have promoted that this material has a prominent place in current research and technological development agendas [7,8].

Compressed earth blocks (CEB) are pieces obtained by compressing soil inside a mechanical or hydraulic press. The press used present a great variety between manual and automated. The formers are used mainly for low production demands and the latter in industrialized systems. There is also diversity in the matrices used with which solid, hollow and embedded blocks can be obtained [9,10]. Although the blocks can only be made stabilizing by means of granulometric correction and pressing [11] is usual to resort to chemical stabilization with cement and/or lime to increase the mechanical resistance and avoid their erosion by weathering [12].

In particular, the CEB building has had special interest in the last 30 years and the intense research on this technology has allowed improve its durability against climatic conditions, increase its mechanical resistance as well as optimize its thermal insulation capacity and hygrothermal performance [9,13–16]. On the other hand, some authors highlights CEB as an economically accessible and ecological constructive system with better mechanical resistance and durability properties than adobe constructions [4], other ones point out its industrialization potential for the manufacture of the blocks and the lower energy consumption involved in the production process — compared to solid brick, hollow brick and concrete block —, according to it allows reducing the amount of energy required for manufacturing, transportation and construction [17,18].

The soil-cement used in CEB manufacture has presented a large trajectory of application in road-engineering, however, its use in building has been after the 1940s [14]. Formerly, the first experiments consisted of manufacturing blocks only of earth in moulds and manually compacted with wooden rammers [19]. The development of CEB building technology, as it is known today — through the use of soil-cement and presses —, began in Colombia at the CINVA Centre (*Centro Interamericano de Vivienda y Planeamiento*) in the beginning of the 1950s and linked to social projects. It emerged as a low-cost alternative for the manufacture of constructive elements and the possibility of self-production of the CEB on-site; currently, it is a very widespread modern earthen construction technology and one of the most regulated in the world [20,21]. This last aspect is fundamental given that the regulations play an important role for the earthen building by giving it visibility, collaborate in dismantling prejudices and confer a greater degree of safety to construction [21–23].

Argentine has a large earthen building tradition, however, it lacks the guidelines to regulate its developments so far, it barely has some imprecise municipal regulations [24]. Contrarily, the antecedents of catastrophic earthquakes of 1944 and 1977 that occurred in the province of San Juan have caused government agencies to discourage or prohibit the earthen construction. To this background must be added the health problems derived from Chagas-Mazza disease that still persist in several sectors of rural areas linked to precarious and poorly executed constructions with adobe or wattle and daub techniques. These issues have increased the prejudice of the use of earth as a material construction [25,26]. Nevertheless, the wide trajectory and the accelerated technological development of earthen buildings are making it possible to solve these inconveniences and disarticulate prejudices; this favours the realization of safer and healthier constructions, as well as being more environmentally sustainable [28–31,112].

The Argentine regulations CIRSOC 501 [32] and CIRSOC 103 Parte III [33] do not mention earth as a construction material, nevertheless they allow the use of materials other than those specified as long as they fulfil the requirement established for ceramic brick and concrete block. Thereby, CEB is presented as a legally viable block to be used [34]. Despite this possibility, there is no CEB type with technical aptitude certification in the local market so far.

The first technological development actions of CEB constructions in Argentine began at the end of the 20th century in parallel from academic and state spheres. The common axis of development has consisted in the search of alternatives systems for sustainable building [35,36]. The importance given to technical research on soils and local uses [37] has been accompanied by the interest of linking with the social environment. An initial strategy — replicated on repeated occasions — has consisted of technological transfers from academic spheres or from specific public policy programs to popular sectors. The first antecedents go back to the 90s through the state construction of bioclimatic rural housings [38]. From there, effort have been intensified by frequently resorting to experimental prototype [39–41] or social projects for self-construction, including the on-site manufacture of blocks [41]. At present, these experiences are presented in an isolated and discontinuous way.

In general, Argentine researches have focused on technical development of the block, while technological transfer processes have placed their interest in the implementation of manufacture units with different work dynamics; in any case they have evaluated the difficulties that proposed technological changes imply, which are not usually few. Although there have been abundant references to the potentialities of earthen construction, like any development to be implemented, it always requires the design of a product, a production process or an organization type according to the context in which it tries to be implemented. On the latter, there are emerging problems that hinder the implementation, dissemination and, especially, the economic support of the CEB manufacture and commercialisation in Argentina; or they make it impossible for technological transfer processes to replicate with greater impact [41]. Even, the antecedents of production process that do not require commercialisation phase are also evaluated as discontinuous and not very successful. The objective of the article is to characterize and discuss the nature of the problems that hinder a greater dynamisation of CEB construction technology in Argentina.

1.2. Production process of CEB

The CEB production process is integrated by successive stages that include from the extraction of raw materials to the use of block on site: manufacturing, commercialisation and construction (Fig. 1).

The CEB manufacturing takes place in a production plant whose size and characteristics depend on the level of planned production; the scale is also in relation to the number of blocks produced per day. Therefore, in low production (less than 250 CEB/day) the manufacturing process is manual and is frequently used in cases of self-construction. For higher volumes, the blocks are manufactured

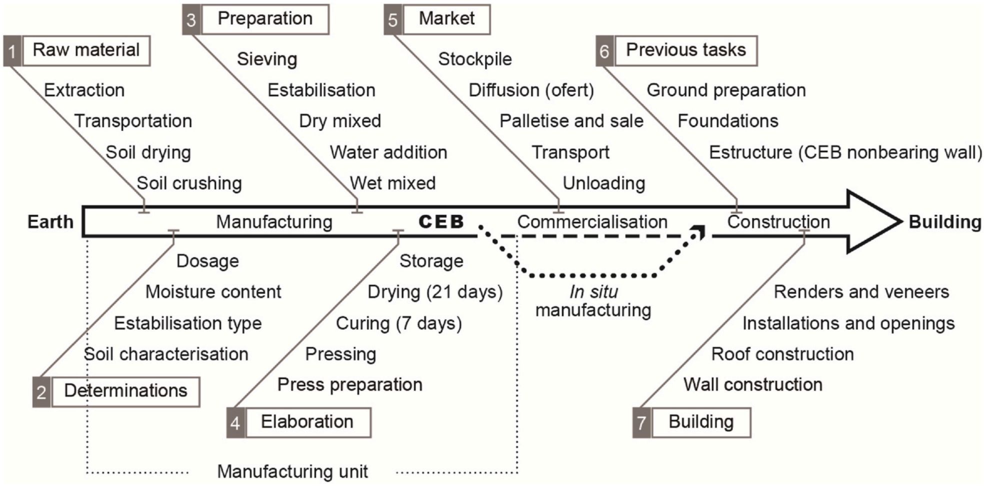


Fig. 1. Diagram of the different stages (1–7) of CEB production process for this study.

in industrial plans of medium (between 250 and 1000 CEB/day) and large-scale (more than 1000 CEB/day). In the latter, the availability of equipment is very important because practically the entire manufacturing process is mechanized, even automated [9]. At present, in Argentine are functioning eleven CEB factories of which there are only two factories in Argentina with the capacity to produce more than 1000 CEB/day, both in the province of Santa Fe (in Arroyo Leyes and Rafaela cities); the rest of the productive factories are of medium and low scale.

Manufacturing stage involves the deployment of at least three phases [9,42]. The first includes obtaining and transport of raw material from quarry and its subsequent determinations: soil characteristics, stabilization type, definition of the optimum moisture content for pressing and mixture dosage (Fig. 1:1–2). The second phase corresponds to the preparation and stabilization of the soil, including mixing it with different equipment (Fig. 1:3). Despite not being strictly necessary the incorporation of mineral stabilizers (cement, lime) in the CEB manufacture [43], in Argentina it is a very common practice (and recommended) since it significantly improves resistance and durability, also allowing the use of soils that do not strictly comply with the recommended granulometric and clay content. Lastly, the third phase embraces the pressing to obtain the block and the curing. Curing requires a minimum period of seven days in a wet and controlled environment and the period in which it acquires its resistance — approximately 28 days —, during which the blocks must be stored for drying in an environment protected from sun and wind (Fig. 1:4). In this phase, a team of people is required, the number of which will vary depending on the scale and complexity of the manufacturing.

When CEB production processes proceed to the commercialisation stage (Fig. 1:5), other factors come into play, such as the free market relation (supply-demand) of the product, the logistics applied in the distribution, the commercial competitiveness strategies, the determination of prices, etc. This scenario becomes more complex due to the need to articulate with local construction habits or confront to the economic and technical competitiveness of conventional construction materials compared to CEB (solid ceramic brick, hollow ceramic brick and concrete block). However, when CEB are manufactured on-site, the commercialisation stage is not involved.

The CEB construction stage does not differ greatly with respect to building with other traditional materials such as adobe masonry or ceramic brick (Fig. 1: 6–7). However, the possibility of interlocking between blocks and the regularity of their dimensions favours the reduction of the base mortar used (generally a mixture of earth and cement). On the other hand, a neat construction of the wall makes it possible to dispense with the renders and expose the CEB in sight, thus reducing work times and costs. In addition, holed blocks and gutter blocks are designed to constitute structural reinforcements within the wall and carry out the passage of the installations —gas, water, electricity, communications— and, thus, reduce construction waste.

1.3. Production processes in the territory

As indicated, CEB production requires the assembly of a more or less complex manufacturing plant according to the scale of production. These constitute the manufacturing units that, through the application of a technical procedure, transform raw materials into products and services (Fig. 1). Like any manufacturing unit, it exchanges products and services in markets located in specific territories and forms part of production processes that are integrated into local society [45,109]. So that production processes are not isolated manufacturing or assembly lines, quite to opposite, they are activities inserted in local production — in which various individual and collective agents, local and foreign, participate systematically in manufacturing, development, distribution, marketing and use of the product— and, therefore, conditioned by social, economic, technical and even political aspects of the place where they are developed. Therefore, they acquire social and economic characteristics by means of which they manage to articulate in this territory [46,47], which provides human capital, natural resources, demands, technological development, infrastructure and the market in which the activity takes place and, at the same time, is where any technological development will be implemented [48]. For this reason, the territory in which an activity or production process is inserted is one of its main components in its economic and productive dynamics, due to the reciprocal influence that occurs [49]. The lack of consideration of these issues brings with it difficulties in the development and implementation of technologies.

Taking into account territorial aspects of the production processes (social, economic, productive, ecological, among others), the CEB production in Argentina has been implemented mainly by the State for the construction of public works, but in a marginal way and in specific cases for housing and school buildings. The implementation experience in the province of Chubut has been based on the attention to the housing conditions of dispersed rural populations in semi-desert areas. In this case, the production of social housing for low-income populations is proposed under a local CEB production scheme and self-construction [38]. Similarly, it occurs with the school constructions in rural areas of the province of Catamarca, where efficiency in construction was sought through the use of local materials with the incorporation of local labor in the CEB production [50]. In the province of Tucumán, the Materials Provision Program of the Provincial Housing Institute, used the CEB technology as a possibility of self-production of blocks and generation of local capacities for low-income families and those living in poverty [41].

1.4. Technologies as a framework for production processes

Technologies are expressed as actions (cognitive, material and practical) carried out consciously by humans in order to alter or prolong the state of things, so that they perform a use or situated function [51]. In this sense, technologies are interpreted from three ontological levels in which they are developed: as technologies of product or device (machinery, tools, utensils, instruments, etc.); as technologies of process, referring to the entire set of skills, methods, procedures; and finally as forms of organization, understood as all the varieties of technical procedures (rational, productive), social (factories, workshops, bureaucracies, research teams), and also public policies (policy instruments, monetary systems, laws and regulations). In addition, as they are in relation to the socio-historical scenario where they are found and depend on the rationality scheme of the social group that implements them, they are neither universal nor autonomous, that is, they do not develop in the same way in different places and moments [52]. Production processes, being technological forms, respond to these frames and always require adaptation for their implementation.

The latter is related to the notion of functioning or non-functioning of a technology, an aspect that does not depend on a technical question or the device itself. This notion is constructed by users through the determination of the meanings that they give it. A device is considered to function when it offers a solution to a problem observed by social groups. In this way, each social group will build its own notion of how the device functions, and this means that the incorporation of a technology –in a specific territory and technological framework– will depend on that social will. The functioning of a technology is not the cause of its success, but the result of having been accepted as a solution to a problem posed by one of the social groups that uses it [53].

Another important aspect to point out are innovations as processes of change in technologies. Innovation is a non-linear process that occurs when organizations, consciously or unconsciously, develop better or new products, processes or modes of production and commercialisation, which reach the market stage; that is, they are successfully commercialised [54,110]. Technological innovation processes are conceived as changes implemented by organizations for social contribution as well as for strategic positioning in the market. Innovation, in any production process, is the basis for its maintenance over time, development, growth and competitiveness in a given context. In fact, CEB has been repeatedly proposed as an innovation within earth building technology [4,56,57].

1.5. Technological transfer of production processes

The technological development associated with CEB in Argentina has a long history in academic and research units, which have become fundamental agents for its transfer to the environment. They have applied strategies and mechanisms of technology transfer among the great diversity of available modalities, from services and alliances with companies or social organizations to the joint development of new products [58]. In particular, the issue of technological developments for social housing has been repeatedly addressed through workshops, training, the construction of prototypes, etc. [59]. In the field of earthen construction, these processes have been characterized by being direct and lineal transfers. They are based on the development of new construction systems or modifications to existing ones in the field of laboratories and then be presented to the community proposing their implementation, but without considering in depth the problem to which they provide solutions or feedback processes that allow the incorporation of diverse knowledge during the practice or implementation space [60–63].

In recent times, these types of transfer processes have been criticised due to their linear and universal character. Because of only correct technical performance is generally weighted, it has been considered that it should be transferred and taken up by the community, independently of the socio-historical and technological scenario in which it is inserted [64]. However, when these processes go beyond the linear vision of traditional transfer, incorporating instances of feedback and complementarity of knowledge and capabilities among the participating agents, the activity acquires the dimensions of a technological linkage process with qualitatively better social results [65,66].

2. Methodology

In Argentina there are no official records that monitor the productive activity of earthen construction, largely due to the lack of regulations that control its production. For this reason, the study focused on the search and analysis of various complementary sources. The methodological process adopted for this research is shown in Fig. 2.

In the first instance, published information on CEB production in Argentina was compiled considering articles from scientific journals, conference proceedings and theses published in the last 20 years between 2000 and 2020. The following online libraries of scientific journals were consulted: Scielo, Dialnet, Scopus, ScienceDirect and the institutional repository of CONICET (National Scientific and Technical Research Council) from Argentina. This list was complemented with the information available in the digital repository of PROTERRA Network [67] that brings together the main scientific contributions of earthen construction for the

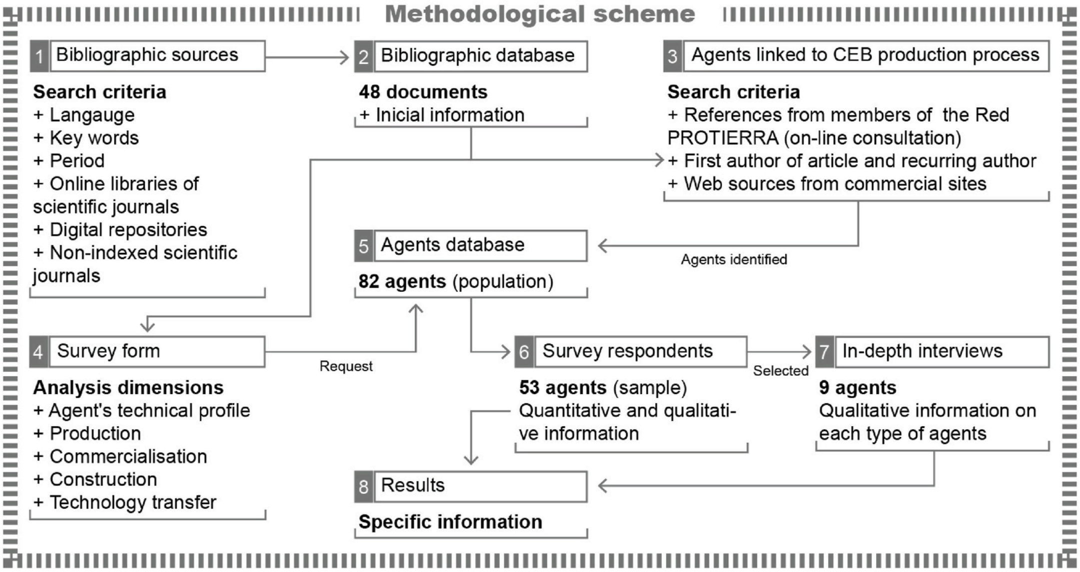


Fig. 2. Methodological scheme designed for the study.

Table 1
Survey structure.

Questionnaire
Expertise
1. Main activity
2. How many years have you developed activities related to CEB?
3. Do you continue with such activities?
4. How did you come into contact with this technology?
Manufacturing aspects
1. If you were linked to a CEB manufacturing process, how difficult was it to get soil?
2. If you manufactured chemically stabilized CEB (cement, lime or others), how difficult was it to determine the amount of stabilizer?
3. If you manufactured CEB, did you have space problems to produce and storage blocks?
4. If you have used workforce for the CEB manufacturing, did you have problems associated with this?
5. If you manufactured CEB, did you have problems with the quality of the blocks obtained? What problems did you have?
6. Based on your experience, what do you consider to be the main problems during the CEB manufacturing stage?
Commercialisation aspects
1. If you bought or sold CEB, did you have problems related to the transport of the blocks?
2. If you bought CEB, did you have problems with the availability in the market?
3. If you have sold CEB, did you have problems to market them?
Construction aspects
1. If you built with CEB:
a) did you sought public or private financing? In affirmative case, did you have problems accessing credit?
b) did you have problems associated with workforce?
c) did you have any problems getting approval for municipal plans?
d) did you notice any construction problems associated with this technique?
Technology transfer and training aspects
1. Did you participate in technology transfer with CEB? In affirmative case, where did the experiences take place?
2. In these experiences, what type of transfer strategies were applied?
3. In theoretical technology transfer experiences, did you observe any difficulty?
4. If you participated in practical training for manufacturing and construction with CEB, did you observe any problem?

Ibero-American area, the conference proceedings of TERRA congress (World Congress on Earthen Architectural Heritage) and non-indexed journals related to the topic addressed were reviewed. The following keywords were used for the search, in English and Spanish: CEB (*BTC*), earth compress block (*Bloque de tierra comprimida*); ecological brick (*ladrillo ecológico*); soil-cement (*suelo cemento*) and Argentina (*Argentina*).

In the second instance, a database of agents involved in the contemporary development of the CEB production activity in Argentina that would be part of the study population was established. This search was carried out through the following channels: 1) the first authors and those who registered with more than one appearance in the articles found were considered; 2) Information on agents

		Frequency	Percent
Sex	Man	36	67,9
	Women	17	32,1
	Total	53	100,0

		Frequency	Percent
Role	Machinery manufacturer	2	3,8
	Builder and self-builder	7	13,2
	CEB manufacturer	7	13,2
	Professional	15	28,3
	Academic	22	41,5
	Total	53	100,0

		Frequency	Percent
Origin	Center	30	56,6
	Patagonia	4	7,5
	Northeast	2	3,8
	Northwest	12	22,6
	Cuyo	5	9,4
	Total	53	100,0

		Frequency	Percent
Trajectory	Less than 5 years	28	52,8
	Between 5 to 10 years	9	17,0
	Between 10 to 15 years	9	17,0
	Between 15 to 20 years	3	5,7
	More than 20 years	4	7,5
	Total	53	100,0

		Frequency	Percent
Status	Active	36	67,9
	Inactive - 5 years	15	28,3
	Inactive + 5 years	2	3,8
	Total	53	100,0

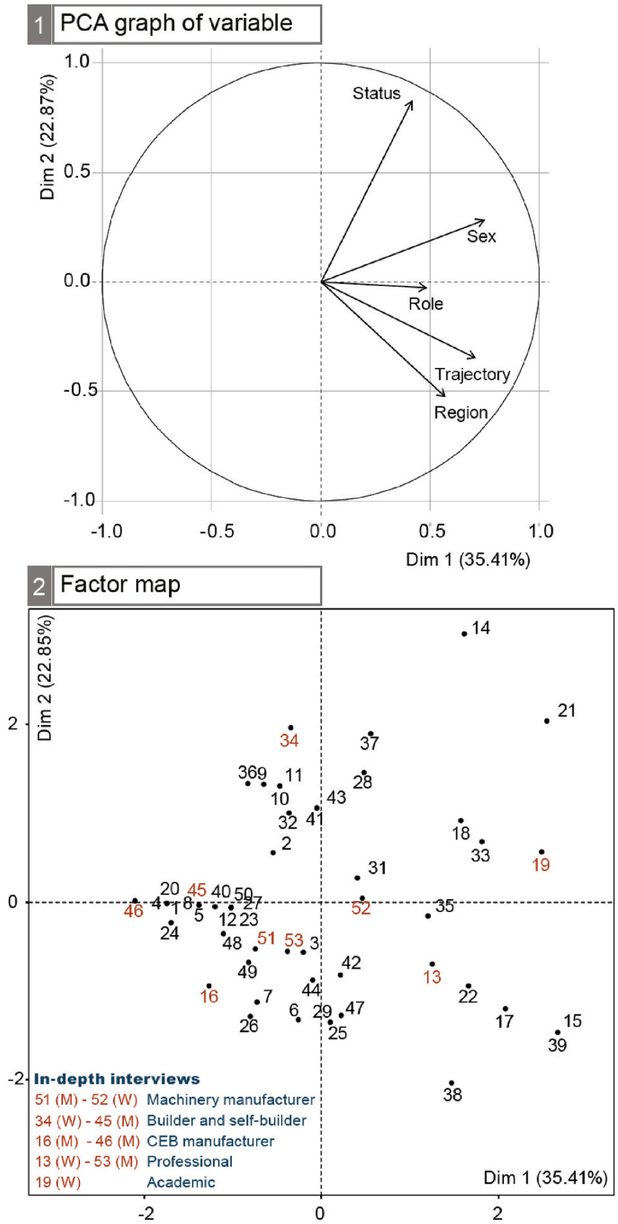


Fig. 3. Characterisation of agents (survey respondents). In the Factor map: M: men, W: women.

linked to the production of CEB in Argentina was requested from the members of the Argentine network of earthen building, Red PROTIERRA [68]. With the information provided, the database was later expanded by applying the snowball technique [69] to detect other agents; 3) Web sources from commercial sites were consulted.

In the third instance, a survey was designed and executed using a Google electronic form to the agents included in the database prepared, previously contacted by email or phone. The electronic form was structured in five sections, the first one consults the survey respondents about professional data, personal interests and work history in relation to CEB. The four remaining fields collected information on the dimensions of manufacturing, commercialisation, construction and technology transfer. The questions in each section had the multiple-choice format, with the possibility of incorporating additional information (Table 1). Once the time stipulated for the survey was completed, a database with the results was prepared and the statistical-descriptive analysis of the responses obtained through the IMB SPSS program [70] was performed.

In a fourth instance, in-depth interviews were conducted with key actors in the production process, selected from among those surveyed. To identify these actors, the survey respondents were divided into representative categories according to the role they play in relation to the CEB technology: 1) academic, 2) professional, 3) builder and self-builder, 4) CEB manufacturer, 5) machinery manufacturer. The criterion applied for these categories construction was to identify agents that participate in different stages of the

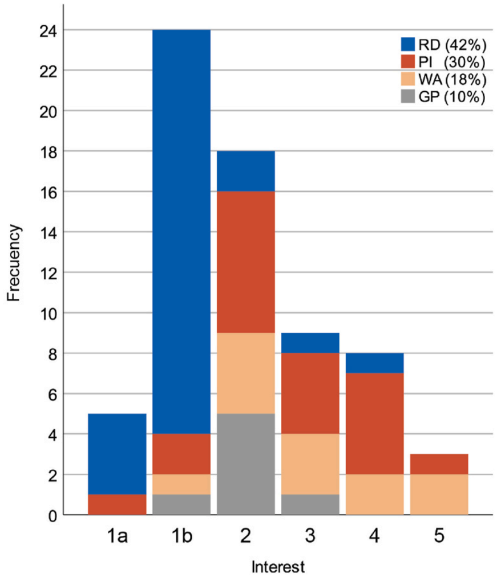


Fig. 4. Interests of agents in CEB technology development. 1a) undergraduate students; 1b) researchers, professors and PhD students; 2) professionals; 3) builders and self-builders; 4) CEB manufacturers; 5) machinery manufacturers. RD: research and development; PI: personal interest; WA: work activity; GP: government projects. The frequency represents the number of responses, more than one per survey agent being possible.

production process. In this way, it was sought to expand the information about the emerging problems in each production stage and control, with qualitative information, possible biases in the interpretation of the results derived from an eventual over-representation of the groups considered. For this, at least one interviewee was considered for each category and maintaining an equitable relationship between men and women.

Additionally, a Principal Components Analysis (PCA) was carried out to explore the diversity of actors who participated in the survey and verify representativeness. The analysis was carried out using the statistical software R [71] with the FactoMineR package endorsed by CRAN [72] considering the variables: sex (men, women), role (academic, professional, builder and self-builder, machinery manufacturer, CEB manufacturer), status (active or not active), region (Centre, Cuyo, Northwest, Northeast, Patagonia) and trajectory (years linked to the subject). The SPSS program was used for a frequency analysis of the variables considered.

As seen so far, in the definition of the study population, one of the main agents involved in the development of a technology, the final users, was not considered. The reasons for its exclusion in the part of this study respond to: 1) the contributions of users in relation to the emerging problems of technology are very different from those of its production process. This was detected from interviews carried out with users, where it was identified that their perception of the problems required to be analysed with a different methodological approach and in greater depth in a second part of the study. 2) In this first part, the objective of the article focused on the perception of the agents involved in the manufacture, their commercialisation, construction and technology transfer.

The analysis of the factors that appear as problems for the CEB development is organized considering the four indicated dimensions: manufacture, commercialisation, construction and technology transfer. In each of these dimensions, the identified factors were developed and in this way the results and discussions were structured.

3. Results and discussion

3.1. Agents

Through the different sources considered, at least 82 agents linked to the CEB production process in Argentina have been detected (Fig. 2). 53 answers to the survey were obtained, this value represents 65% of the population considered. On the total number of survey respondents, nine in-depth interviews were carried out. The characterisation of survey respondents was carried out (Figs. 3 and 4). Analysing the activity of the survey respondents, five profiles were identified in the group of agents: 1) academics (included a) undergraduate students, b) researchers, professors and PhD students), 2) professionals from government agencies and white-collars (architects and engineers the vast majority), 3) CEB manufacturers, 4) builders and self-builders, 5) machinery manufacturers.

According to their activity, two categories have been established to classify them:

- First category: Academics field: Teaching, research and transfer (profiles 1a and 1b, 22 surveys (41,5%)).
- Second category: Non-academic field: Manufacture, commercialisation and construction (profiles 3 to 5, 31 surveys (58,5%)).

The CPA carried out to analyse the profile of the survey respondents (according to the five variables considered), allowed to reflect in the first two dimensions of analysis 58.28% of the diversity and characteristics of agents that make up the sample under study. The dispersion is explained mainly from the incidence of the status and trajectory variables. The first one, in relation to whether or not it is developing some activity with the CEB, causes the most general atomization among the agents in the vertical direction, the assets being those that are in the lower cloud. The second, organises the agents according to the time that they have linked to the CEB production.

Table 2
Scientific production database.

N°	Ref.	Resource	Type	Field	Origin	N°	Ref.	Resource	Type	Field	Origin
1	[73]	Mellace et al., 2002	Congress	Research	Tucumán	25	[90]	González et al., 2017	Congress	Research	Santa Fe
2	[74]	arias et al., 2003	Congress	Research	Tucumán	26	[10]	González and Cabrera, 2017	Congress	Research	Santa Fe
3	[75]	Arias et al., 2004a	Congress	Research	Tucumán	27	[91]	González et al., 2018	Congress	Research	Santa Fe
4	[76]	Arias et al., 2004b	Congress	Research	Tucumán	28	[92]	Benvenuto et al., 2019	Congress	Research	Santa Fe
5	[40]	González et al., 2004	Congress	Transfer	Santa Fe	29	[93]	Cabrera et al., 2019	Congress	Research	BsAs/Santa Fe
6	[77]	Rotondaro et al., 2004	Congress	Transfer	Buenos Aires	30	[34]	Dorado et al., 2019	Congress	Research	Tuc/Santa Fe
7	[37]	Alderete et al., 2006a	Congress	Research	Tucumán	31	[41]	Jerez Lazo et al., 2019	Congress	Transfer	Tucumán
8	[78]	Arias et al., 2006	Congress	Research	Tucumán	32	[94]	Alderete et al., 2006b	Article	Transfer	Tucumán
9	[79]	Begliardo et al., 2006	Congress	Research	Santa Fe	33	[95]	Ortega Arguibay, 2007	Article	Transfer	Tucumán
10	[80]	Ferreyra et al., 2006	Congress	Research	Tucumán	34	[96]	González et al., 2007	Article	Transfer	Santa Fe
11	[81]	Galindez, 2006	Congress	Research	Salta	35	[97]	Rotondaro, 2007	Article	Transfer	Buenos Aires
12	[82]	González et al., 2006	Congress	Research	Santa Fe	36	[39]	Mas et al., 2011	Article	Research	Tucumán
13	[60]	Pautasso et al., 2006	Congress	Transfer	Santa Fe	37	[98]	Patrone y Evans, 2012	Article	Research	Buenos Aires
14	[83]	Pollioto y Galindez, 2006	Congress	Transfer	Salta	38	[99]	González y Lazzarini, 2014	Article	Transfer	Santa Fe
15	[84]	Sánchez et al., 2008	Congress	Research	Santa Fe	39	[111]	Cacopardo et al., 2018	Article	Transfer	Buenos Aires
16	[43]	Galindez, 2009	Congress	Research	Salta	40	[101]	Rotondaro and Mandrini, 2018	Article	Transfer	BsAs/ Córdoba
17	[61]	Pardo et al., 2009	Congress	Transfer	Santa Fe	41	[102]	Lema, 2019	Article	Transfer	Salta
18	[85]	Mingolla et al., 2011	Congress	Transfer	Santa Fe	42	[30]	Cuitiño et al., 2020	Article	Research	BsAs/ Mendoza
19	[86]	Rotondaro et al., 2011	Congress	Transfer	Buenos Aires	43	[103]	González et al., 2020	Article	Transfer	Santa Fe
20	[87]	Rotondaro et al., 2012	Congress	Transfer	Buenos Aires	44	[104]	Lucas et al., 2020	Article	Research	San Juan
21	[63]	Mas et al., 2016	Congress	Transfer	Tucumán	45	[29]	Cabrera et al., 2020a	Article	Research	BsAs/Santa Fe
22	[88]	Rotondaro and Cacopardo, 2016	Congress	Transfer	Buenos Aires	46	[105]	Cabrera et al., 2020b	Article	Research	BsAs/Santa Fe
23	[50]	Walter et al., 2016	Congress	Transfer	Catamarca	47	[106]	Butynski et al., 2017	Thesis	Research	Mendoza
24	[89]	Cacopardo et al., 2017	Congress	Transfer	Buenos Aires	48	[107]	Barrozo, 2019	Thesis	Research	Tucumán

Again, those with less trajectory also characterize the indicated atomization. The sex variable reinforces the atomization given by status variable, but does not generate atomization by itself. Finally, the region variable, largely correlated with trajectory, shows that those of agents located to the right of the distribution belong to the Northwest region while those to the left to the Centre region. In summary, it is possible to indicate that the most evident atomization is made up of agents with less than 5 years of experience, active and mainly from the central region. If this composition is observed and compared with Fig. 6, we will see that this group is associated with the region with the most research activity, but also the one with the most production facilities and the largest of them, that is, the most active region in the current development of BTC technology.

On the other hand, the nine agents who were interviewed in-depth are indicated in the Factor maps coloured in orange. It is appreciated that their selection allowed having diversified qualitative information not only on the representativeness of sex but also with respect to the other variables considered in the PCA.

Additionally, it was verified if the size of the sample reached was within statistically acceptable parameters. Using the next formula to estimate the size of samples with known finite populations whose main variables are qualitative and considering a confidence level of 95%, the margin of error was 8%:

$$d = \sqrt{\frac{\frac{NZ^2pq}{n} - Z^2pq}{N-1}}$$

where:

d = margin of error
n = sample size (53)
N = population size (82)

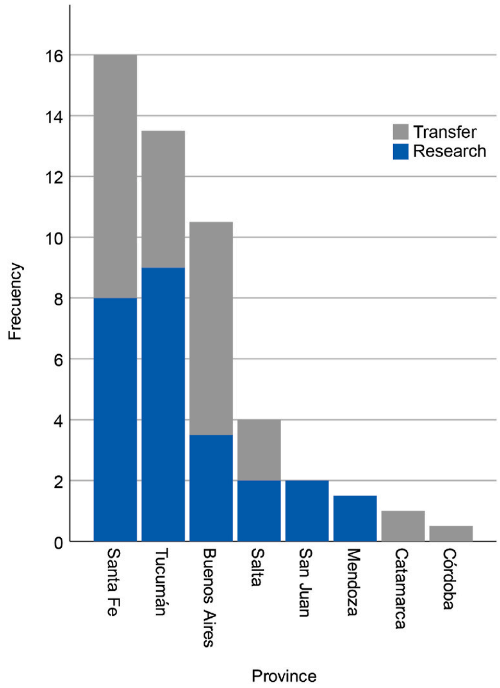


Fig. 5. Research and technology transfer papers by province according to scientific production between 2000 and 2020. In the case of Buenos Aires, University of Buenos Aires (Buenos Aires city) and National University of Mar del Plata (province of Buenos Aires) productions were unified by their joint work trajectory.

Z = confidence level (95% = 1,96)
p = approximate proportion of the phenomenon under study in the population (0,5 adopted)
q = proportion of the population that does not present the phenomenon under study (1-p)

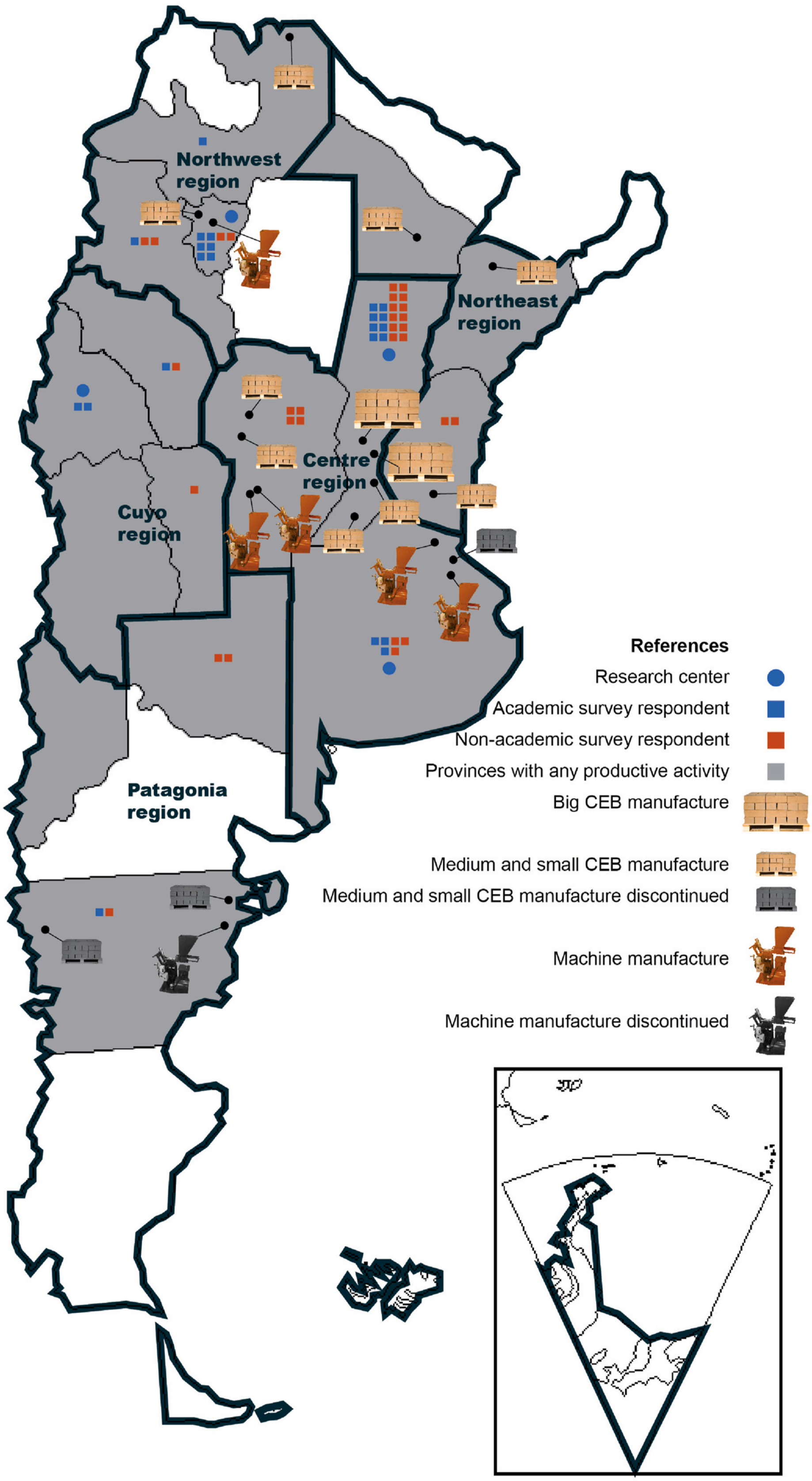
3.2. Activities

In addition to the diversity of agents, a multiplicity of activities involved was also detected. A first group of them are those developed from the academic field: research, teaching and technology transfer focused on the technical CEB development. The university centres involved in the research and teaching are located in the provinces of Tucumán, Santa Fe, San Juan and Salta. In Tucumán, trajectories of 25 years of development have been registered, involving three different groups from the National University of Tucumán. In Santa Fe, the activity has been developed at the National Technological University, at its regional headquarters in Santa Fe and Venado Tuerto cities, with 20-year trajectories. In San Juan, the activity has been taken over by the Regional Institute for Planning and Habitat. In Salta, the investigations have been carried out by a group of researchers from the Catholic University of Salta. These same centres have carried out technology transfer activities with social organizations and technical advice to small and medium manufacturers. In these transfer activities, two groups belonging to the University of Buenos Aires and the National University of Mar del Plata can also be considered, which have carried out transfer activities jointly for 12 years, but without being directly involved in technical development. At the National University of La Rioja has been conducted teaching and transfer activities. In the last three years there has been greater collaboration between different research groups, where Buenos Aires and Santa Fe are the main promoters. Table 2 shows the scientific production database for the last 20 years, containing papers, articles in conference proceedings and theses. A balanced production is observed between topics related to research (25) and technology transfer (23), but with different profiles according to each province (Fig. 5). The research centres of Tucumán, Santa Fe and Buenos Aires have concentrated 83% of the total production throughout the indicated period.

In the activities corresponding to manufacturing, commercialisation and construction, trajectories of between 4 and 15 years are identified:

1. In the case of manufacturing, it is possible to differentiate two branches of activity: on the one hand, those linked to the activity of industries that manufacture blocks or machinery; on the other hand, those CEB on-site manufacturing activities for government construction (housing and school buildings) or in private works.
2. In the case of commercialisation, there are also two branches, which are complementary: the commercialisation of machinery and the blocks.
3. In the case of construction, the activity is diversified according to the type of work: construction of building on demand by professionals, construction of turnkey housing, self-construction and construction by the government agencies.

When considering all the activities indicated, it is verified that the CEB construction has a wide diffusion in the Argentine territory.



(caption on next page)

Fig. 6. Distribution and type activity linked to CEB technology in Argentina.

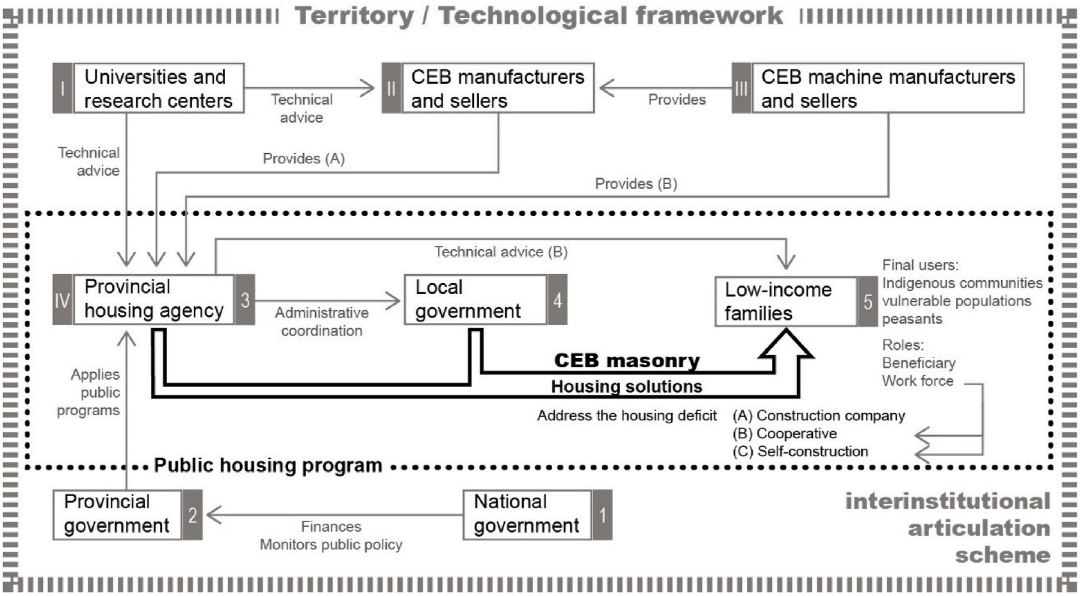


Fig. 7. Scheme of Inter-institutional development using CEB technology for the social housing construction in the Chubut province. I-IV agents analysed in this study, 1-5 actors linked to public housing programs.

They have been observed in development in at least 17 provincial jurisdictions (including Buenos Aires city) out of 24 that integrate the country (Fig. 6).

3.3. Previous approaches to CEB problems in Argentina

When analysing the database on the scientific production of CEB, it was detected that some works address problems related to the CEB production, but in all cases not focusing on more than one or two issues in particular. The topics addressed are related to equipment maintenance [77], incorporation of quality control processes, on-site technical support and inter-institutional work [40,85,96,97]; including its possible association with the use of local materials [35,61,63] and contributions to the labor insertion of women in construction [60]. Methodologies for the CEB implementation have also been evaluated, considering the perception of the final user and incorporate the concept of appropriate technologies, design processes and the participation for the management of production plants [87,88,111]; Butynsky et al. [106] and Benvenuto et al. [92] have evaluated the CEB production incorporating market studies, the competition with other conventional construction systems and the costs involved in the construction of a CEB plant; Jerez Lazo et al. [41] have recorded houses with 15 years of use to evaluate the CEB performance and the management model implemented in a public program for the construction of social housing, the appearance of pathologies in the buildings and the level of user satisfaction with the construction system implemented. Finally, the systematisation of the CEB implementation problems have been studied in a previous work where only a list of technology implementation difficulties is defined and the nature of these problems is discussed [34].

3.4. Interests and articulations between agents

When inquiring from agents about motivations related to CEB technology, a significant part of the interest has been linked to research and development issues (42%) and corresponds to a large extent with agents in the first category. Among the main topics, the interest in the development and technological transfer of an innovative construction system is indicate, which makes it possible to solve housing needs for vulnerable social groups, which can be standardized and, at the same time, which easily allows on-site manufacturing without compromise the quality of the blocks.

Those agents whose interest has been to use a construction system with an ecological profile — considering the possibility of reducing the carbon footprint in the CEB manufacture as well as reduction energy consumption due to better thermal performance —, available on the market and advantageous to the self-construction collects 30% of the interest shown. Likewise, the agents involved in the CEB manufacture and commercialisation, point out the implementation of this technology as a commercial strategy, a niche of opportunity in the construction elements sale because it is considered an ecological construction system.

When the agents mention that their relationship with CEB has derived from their work activity (18%), their interest is focused on managing the regulation of the construction system, an aspect that they link it with the standardisation of the products quality (block and construction) and improve the training of technical staff for manufacturing and construction labour.

Finally, the interest of the agents of governmental agencies or professionals who have articulated in public projects (10%) is to implement construction systems that allow solving the problem of access to housing, prioritizing the search for alternatives of economic and ecological materials, adapted to the implementation site and favourable for the development of social entrepreneurial ventures for the manufacture of construction material (Fig. 4).

It is worth highlighting the convergence of interests between agents from universities and research centres with those who are linked to the government agencies spheres on access to housing issues for social vulnerable groups. This convergence prompted one of the first development schemes of CEB technology in Argentina from local government and has established a modality of inter-institutional articulation –Provincial housing agency/Universities/Local governments– (Fig. 7). As noted, the first scheme is systematically implemented in the last decade of the 20th century in a rural public housing program built by the government in Chubut with the objectives of improving the housing conditions of indigenous and peasant populations and implementing designs with bioclimatic criteria [38]. In the aforementioned case, self-construction of the housing by the users with technical advice from the agents of the Housing Institute of Chubut was the strategy used. To carry out the program, an inter-institutional articulation was carried out between the Regional Centre for Wind Energy, the soil laboratory of the National University of Patagonia, the Provincial Housing Institute and each of the municipalities in which housing were built. This articulation favoured the development of research on the soils used and the dynamics and construction practices appropriate to the technology employed (L. de Benito, personal communication, June 11, 2020). This case of government interest in the implementation of CEB construction technology, articulated with universities and research centres, has constituted a replicated scheme, with variants, in Tucumán [41], Salta [102] and Catamarca [89], in the latter for the construction of educational buildings.

3.5. Emerging problems in manufacture

Regarding CEB manufacturing, two main problems were identified. The first one is related to the production plant and the second one is related to the quality of the CEB produced.

CEB manufacturing demands large areas covered at any scale of production because, from the collection of the raw material to the curing of the blocks, many of its activities must take place on conditioned spaces [106,108]. In particular, the space for the curing chamber requires more complex surfaces and infrastructures to ensure controlled temperature and humidity conditions [15]. Precisely, the lack of adequate space has been indicated by 60% of manufacturers as the most recurrent problem that they have to face. This can be associated with the lack of a planning and design process for the production plant, since this aspect is not usually considered prior to its installation. In fact, it was detected that small manufacturers are mainly those that do not usually contemplate these prior planning processes in depth. The problem arises when the daily production capacity (fundamental parameter for the design of any production plant) is not duly considered with the space available for curing and storage the raw material and the blocks [92]. In the case of manufacturing units of greater scope and trajectory, it was found that prior space planning processes are implemented, or that their daily production capacity is adapted according to the available surface (W. Spies, personal communication, July 8, 2020). In commercial terms, the lack of planning in production levels has a negative impact on obtaining economic benefits, an issue that is not usually addressed in the literature.

Another recurring problem is associated with CEB manufacture (56%). In this case, two causes are pointed out: a) the lack of experienced technical staff to manage the CEB manufacturing unit: respondents surveyed associate this fact with the use of a new technology that involves the use of specific machinery, knowledge of laboratory tests and specific quality controls to which they are not accustomed; b) quality control of raw materials and CEB produced: this problem is mainly detected in small and medium-scale manufacturers, which do not have the equipment or financial resources to request laboratories to evaluate the quality of the raw material and the blocks. In addition, 35% of the manufacturers said they had problems in obtaining adequate soils for manufacturing and acquiring new machinery.

These issues show that, in general, CEB manufacturing is not assumed as a complex process of a technical and industrialized nature, regardless of the scale of daily production; even the homogeneity in the final quality of the blocks produced is not assured, nor are preventive maintenance programs for the machinery considered. The lack of specific regulations for the CEB manufacture (apart from the CIRSOC 501 regulation) and the absence of standardised procedures for their manufacture exacerbate this problem.

3.6. Emerging problems in commercialisation

Regarding commercialisation, three problems were identified: the relationship of supply and demand of products, the manufacturing scales and the costs involved in commercialisation.

Currently there are three commercialised products: presses, blocks and houses built with this technology. As is known, the CEB manufacture on-site was among the motivations that gave rise to this technology; and the inescapable requirement of machinery has encouraged the early development and commercialisation of different types of presses and complementary devices such as lump breakers, sieves, mixers and homogenisers in the decades after the first manual model appeared [9]. In this sense, according to what the machinery manufacturers interviewed say, it is observed that they have managed to form a market and attend demand without interruption over the last 15 years. Nevertheless, their sales have had to face permanent fluctuations and have hardly had a projection in the local market, where they simultaneously face low demand and commercial competition with foreign suppliers. In the 90s, the first block machines acquired were imported from South Africa and corresponded to manual models. Currently some enterprises have acquired presses from Brazil (R. Marchese, personal communication, June 28, 2020 and L. de Benito, personal communication, June 11, 2020).

Five active agents have been identified that manufacture and sell machinery distributed in the provinces of Buenos Aires (2), Córdoba (2) and Tucumán (1). These manufacturers have diversified their equipment offering and provided pre- and post-sale advice as a strategy to consolidate themselves in the market (training, advice on soils and stabilization, soil characterisation service, etc.). Due

Table 3
Comparison of CEB costs and price per m^2 of built wall in relation to other available materials in the market. Prices expressed in US dollars (Quote 1 USD = 101 $ Arg., consulted 07/20/2021).

Constructive element	Indicative image	Dimensions [cm]	Total cost per unit [USD]	(1) Total cost of materials [USD/m^2]	(2) Total cost of workforce [USD/m2]	Costo total (1) + (2)
Burnt clay brick		22 × 11 × 5	0,22	13,49	10,48	**23,98**
CEB		25 × 12,5 × 6	0,29	18,36	7,34	**25,69**
Hollow clay brick		33 × 18 × 12	1,15	12,45	13,85	**26,31**
Hollow concrete brick		39 × 19 × 13	1,28	15,93	13,81	**29,74**
AAC block		50 × 15 × 15	3,81	25,79	10,34	**36,14**

to low demand and the size of the undertakings and projects, the offered presses have been limited to two models, one manual and the other semi-automatic hydraulic, which is far from the diversity that exists worldwide [9,15].

In the CEB case, its commercialisation assumes an alternative character due to the indicated possibility of on-site blocks manufacture. Numerous experiences of private and government construction have implemented this modality to satisfy their own need [41,50], so the CEB demand is not transferred to the market and it does not favour increase of its commercial dynamics. On the other hand, although the study identified that 40% of the survey respondents participated in CEB commercialisation processes, these activities have been discontinuous and within a very limited market. By focusing on the supply, only 20% of the survey respondents have been involved in the sale and correspond to those who have dedicated themselves exclusively to the CEB manufacture, no indirect or mixed forms of commercialisation were identified, that is, intermediaries between the manufacturer and the buyer, such as the construction material stores. The eleven CEB manufacturers that are currently in activity present a diversified panorama in relation to the infrastructure they have, the manufacture volume they carry out, and the quality and service certification they offer. Only three cases correspond to big companies, two in Santa Fe and one in Córdoba. None of the survey respondents stated that they have been able to place the product on the market in a sustained manner. Likewise, only one of the manufacturer has a sales record of twelve years, the rest barely have around five years in the market with discontinuous and low-impact activities, constituting paralysed industries with a lot of idle time. This panorama shows that the commercialisation conditions have not yet allowed the growth and sustainability of this type of undertaking in the long term. To face this type of problem, two manufacturers, one small and one medium-scale, resorted to a complementary marketing strategy through the turnkey housing production modality. The manufacturers surveyed point out that the problems in commercialisation are associated with the simultaneity of factors: low demand, CEB unawareness, indifferences of builders to incorporate this technology into their activity and the lack of interest of local governments in promoting their development in public works. Builders and professionals point out that one of the main problem reside in the absence of consolidated CEB manufacturers, manifested in the lack of stock or its discontinuity and the quality of the available blocks. Considering these issues, for CEB to prosper commercially, certain conditions are required: its knowledge in the market, the existence of sustained demand, a minimum acceptable CEB quality offered, the permanent stock availability and a competitive cost with respect to other building materials.

If it focuses on the manufacture scale, survey respondents point out that small and medium-sized manufacturers tend to have greater difficulties in guaranteeing an optimal CEB quality. In these contexts, the control of the process and the final quality of the product are usually carried out empirically or with rudimentary tools that do not provide accurate or precise information. In the case of larger-scale undertakings, they have the possibility of accessing other types of equipment or links that allow them to carry out tests to evaluate the quality of the block in laboratories; however, they face cumbersome administrative processes and the long times imposed by the government agencies to conduct the studies. Finally, there is little interest in research focused on problems derived from commercialisation or that analyse the dynamics of the materials market for the insertion of CEB, an issue that also requires localised studies [96]. Nor were any developments identified in the CEB production process that have considered a defined business model or sufficiently clear to achieve the commercialisation of the products and services offered. All adjustments and experience gains reported by survey respondents have derived solely from their own practice.

Finally, the survey respondents point out recurring problems when transporting the blocks to the construction site. The CEB weight (between 3,5 and 7 kg per block) limits the effective amount that can be transferred per trip, independently of the available transport capacity, and reduces the distance of economically profitable transfers. On the other hand, if CEB quality is not adequate, especially of the hollow and interlock blocks, excessive breakage of the blocks usually occurs during transports that negatively affect the sale and image of the product.

The outlook presented shows the incipient situation in which this technology is found in the Argentine market; In this way, commercialisation is identified as the least developed instance of the CEB production process in this country. It should be noted that there is no regulation for the CEB standardised manufacture in the country and this issue does not encourage the construction material stores to offer them as a product. Table 3 shows the comparative CEB price (per unit) and the price per m^2 of built wall, contrasting it with those of other frequently used technology in Argentina.

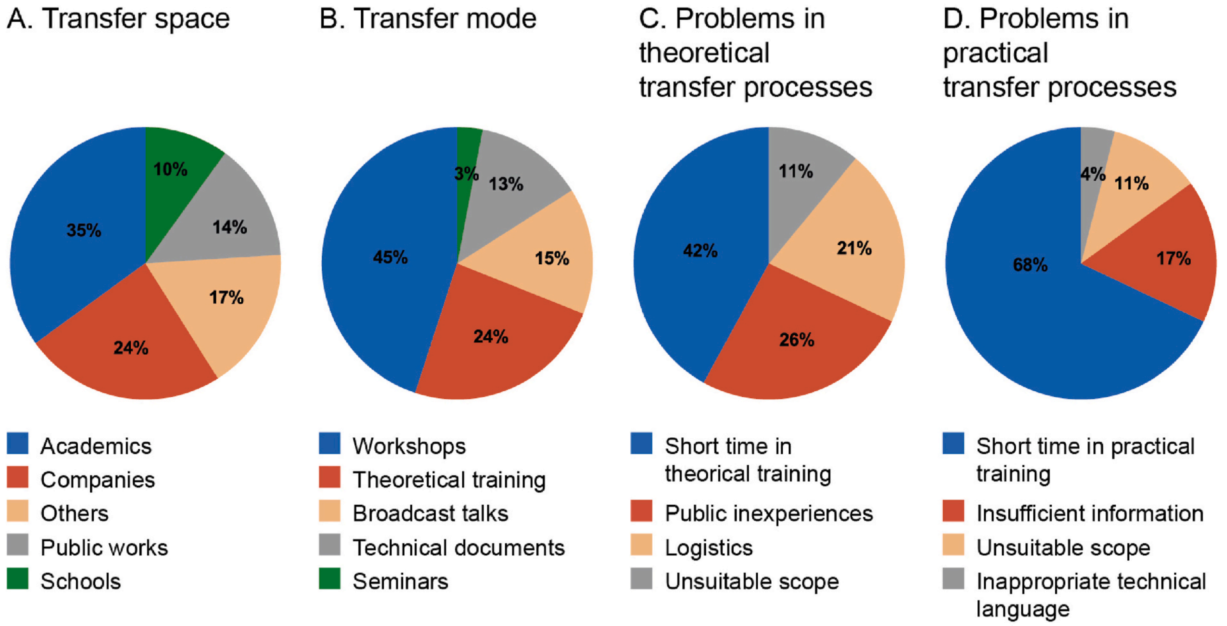


Fig. 8. Problematic aspects of technological transfer.

3.7. Emerging problems in construction

Three main problems were identified for this issue: in the technical-construction aspects, in the labour aptitude and in the access to financing.

Despite having similar characteristics compared to ceramic bricks or concrete blocks building, CEB construction presents certain differences that must be considered before starting the works to avoid future inconveniences. In the case of the interlock CEB, this entails foreseeing modular measurements of the spaces in the design stage, always using the half block as the measuring unit. This issue is faced with local construction and design habits in which such modulation is not usually considered due to the ease of adaptation of traditional construction elements. On the other hand, the base mortar amount used in CEB construction walls is lower, and therefore it is difficult to adjust levelling errors during the walls construction. In this sense, it is important to execute the first course with great care because it will guide the insertion of the upper blocks, directly compromising the quality and ease in the execution of the complete wall. Likewise, the construction system must consider the existence of special blocks for the construction of vertical (perforated blocks) and horizontal reinforcements (gutter blocks) and for the passage of installations, whose location must be respected from the beginning of construction. This aspect again differs with local constructive habits, where these resolutions are made at different times (S. Mercedes, personal communication, June 14, 2020). Another issue related to technical-construction aspects is associated with the lack of specific CEB construction regulations in Argentina. This issue is pointed out by numerous survey respondents as a problem in achieving municipal construction authorisations; a problem that is more complex in seismic areas.

On account of formal and non-formal training systems on CEB construction are infrequent and spaced in time, the lack of eligible labour on the construction system persists. Although every construction process requires investment in the training of its labour, CEB construction has been associated with conventional construction recurrently and it has been assumed that its assimilation by experienced builders should be a simple matter. However, this situation does not happen in practice, both because it is a different construction system, as well as of the difficulties and resistance that survey respondents observed in experienced builders when they employ CEB. For these reasons agents linked to construction point out that the training process has had to start from scratch, practically in each work (M. Macielo, personal communication, May 29, 2020) and with the consequent demands for extra time and investment derived specifically from this circumstance. At the same time, the current small number of CEB constructions does not favour the dynamics of non-formal training through practice on the construction site as is usual in traditional construction.

Finally, the not yet widespread knowledge of CEB technology by financial agents and the lack of regulatory frameworks for the construction system has been observed as a difficulty for credit access, both for private works and for public works financed by the state or by international credit organizations as World Bank, United Nations, IDB, etc. (E. Walter, personal communication, June 23, 2020, [24]).

3.8. Emerging problems in technological transfer

The CEB technology transfer has been observed as a recurring activity promoted mainly from universities and companies to general public (Fig. 8A). An important part of it has been taught in academic spaces through the modality of workshops and theoretical training (Figs. 8B) and 80% of the survey respondents said they had participated in this type of activities. Likewise, the matter constitutes a topic of interest in local research since half of the scientific articles address this question (Table 2). If analysed by category of agents, it was observed that 93% of the survey respondents linked to the first (teaching, research and transfer) have dedicated time from their work to technology transfer tasks, providing training or technical advice to entrepreneurs, companies or general public. In a complementary manner, 72% of agents in the second category (manufacture, market and construction) have participated in transfer activities, either by training or providing training. Many of them even refer to their foray into this technology after having participated in training or outreach activities about CEB. This provides an intense exchange panorama between academic and construction field even when the interests are not necessarily the same by each groups.

When asked about the problems perceived in the transfer activities, the survey respondents indicated the limited time allocated to training and the complexity of the content transmitted to understand in detail the CEB manufacture process and the construction with these blocks (Fig. 8C and D). Some survey respondents recognize the importance of selecting the content to provide in the training according to the profile of the target audience. It is also observed that the interest from academic spheres privileges issues of technical CEB development, leaving aside specific issues related to commercialisation and scarcely addressing issues that concern the organization of the manufacturing unit or the modalities of training for technical staff and labour. This prioritization of research agendas limits the integral development of the CEB production process.

The technology transfer cases described in the literature (Table 2) have had as common objectives to analyse the CEB technology potentiality to address social problems of habitat improvement. In them, the manufacture of construction elements (blocks) is usually presented as a simple, low-cost task and, with respect to the construction system, easy to apply in self-construction, similar to conventional construction systems. However, the activities carried out tend to be of low impact, mainly due to the discontinuity of the activities and the monitoring of the results [36]; and the idea of the technical advantages indicated is contrasted with the rigor of the manufacturing and construction processes with CEB technology. Even, as an interviewee linked to the CEB manufacture and construction points out, for many experienced builders, it requires "a process of unlearning to relearn how to build, because with CEB you build differently" (J. Cisnero, personal communication, August 3, 2020). Survey respondents, for their part, suggest that technology transfer activities aimed at promoting CEB productive ventures, improving the blocks produced and addressing housing access problems, have not fully met the awaited expectations. When analysing the nature of the problems indicated, part of it possibly lies in how they are conceived, how the problem is constructed, what issues are prioritized and what strategies are implemented in the transfer processes, beyond the degree of technification involved in the CEB technology. As some authors point out, when it comes to solving social problems of habitat, the designs of technology transfer processes must abandon linear schemes to be designed based on the analysis of specific needs duly identified and with the active participation of the social groups involved [65]. In this way, the problems to which it comes to provide a solution are adequately defined, the agents involved are actively considered and the technological framework in which it is inserted is recognized.

The transfer and implementation of a technology as a solution to a problem is not a process that happens spontaneously or as a product of the diffusion of innovative technical systems; it is a complex process that depends on the construction of functioning and non-functioning. For recipients, the technology will not work or be incorporated to the extent that it does not meet their own needs. For those who promote the transfer, it will work to the extent that it responds to their objectives: technical development of the product, diffusion of new technologies, proposal of more ecological systems, options to meet the social habitat needs, etc. As long as the construction of functioning is different between recipients and promoters, the CEB technology will not be implemented as a solution to the problems that it is trying to solve.

4. Conclusion

The incorporation of CEB technology in Argentina is a process that, originally, was addressed by government agencies for the social housing production. Simultaneously, it was incorporated into the research agendas in academic fields, through research and transfer projects that sought to install alternative and ecological construction systems, reducing costs in public works, promoting self-construction and using local natural resources. In this first stage, the CEB was conceived as a simple construction technique that is easy to implement and favourable for productive enterprises of a social nature. Subsequently, self-builders and private companies became interested in the ecological and low-cost profile with which this technology was associated; in the case of the latter, considering these aspects as a commercial advantage. From these three areas, the CEB construction technology has been promoted over more than 25 years, it has even experienced a marked intensification in the last time. As a result, the CEB currently has considerable technical development, installed technical capacity and diversification of the actors involved. To this are added productive experiences that have generated background and fundamental learning to continue with their development. However, even when the social and ecological profile has prevailed in its development, a series of structural problems prevent this technology from moving towards a level of greater commercial development and incorporation into local technological frameworks.

The lack of specific regulations on the CEB production, commercialisation and construction is a crosscutting problem to the aforementioned issues; In terms of production, there are no regulations that determine quality standards in production processes, which has an impact on their commercialisation, to the extent that products without quality certification cannot be placed on the market. In construction instances, as it is not included in the building codes, the works must be carried out as an exception or outside the regulations, with the structural risks that this entails mainly in seismic areas. In terms of access to credit, financing of public and private works is difficult. The offer of CEB without minimum quality parameters contributes to the general lack of this technology knowledge and generates mistrust that deepens the problems identified.

The technical aspects involved in CEB manufacturing stage are those that have received the most attention so far. Nevertheless, much of the current difficulties to continue with its development are focused on the implementation, dissemination, economic support of block manufacture, commercialisation, CEB standardisation and the transfer of this technology. Even commercial issues and non-

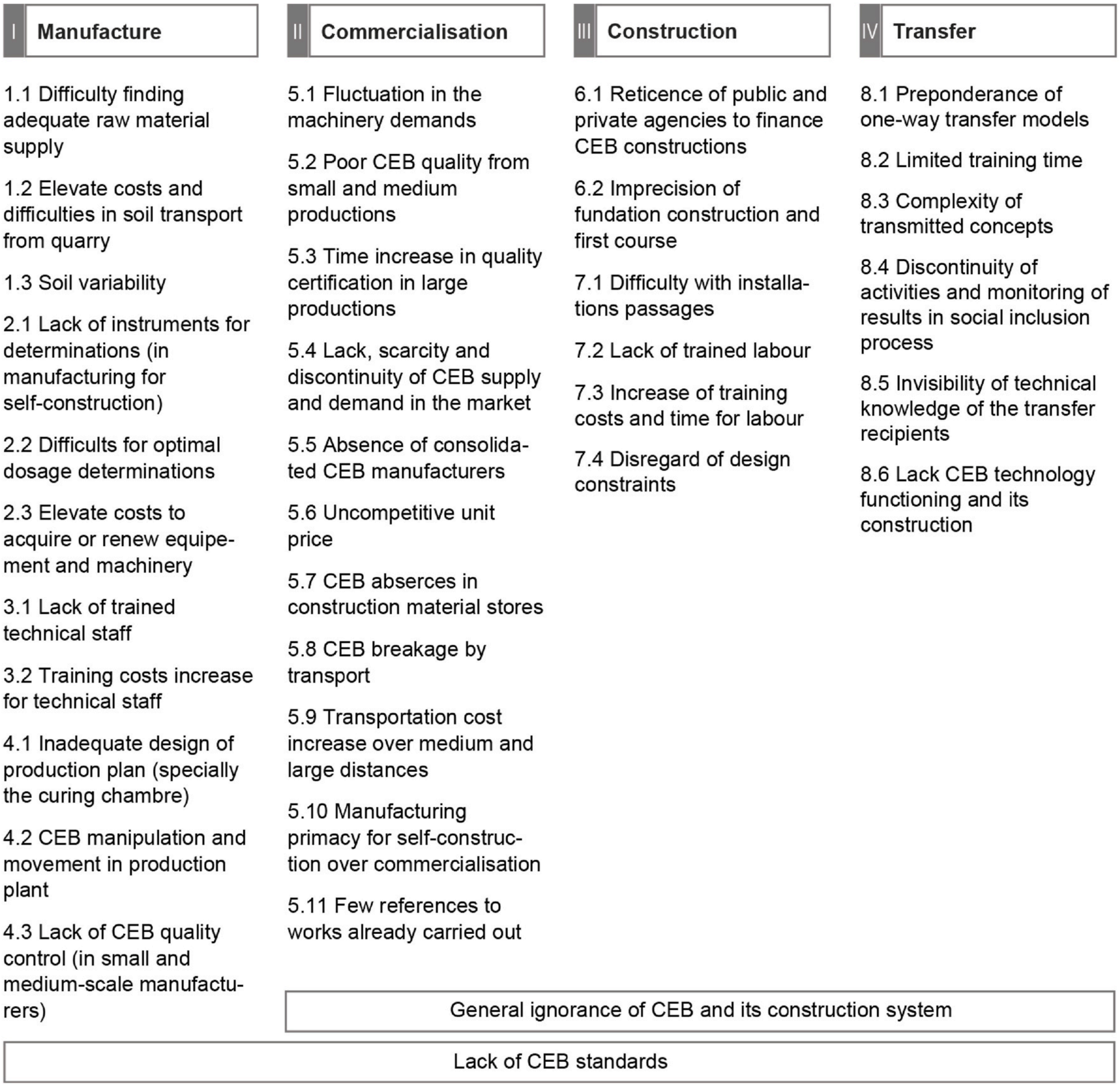


Fig. 9. Summary of the main problems identified in the development of the CEB production process.

linear transfer modalities are the least currently addressed in scientific research. This situation indicates the necessary complementation of these topics in the research agendas, at least at the local level (Fig. 9).

The commercialisation and construction stages meet their most important structural problems in the lack of this technology knowledge that persists, the great difficulty of incorporating the blocks in the conventional market and in the inconveniences to adapt to the current construction and commercial regulations. The lack of this technology knowledge has a similar impact on both supply and demand for the product. The situation is more complex due to the lack of a clear business plan with which the commercial manufacturing units have been assembled and a marketing strategy by their developers, beyond the reference to the ecological and low-cost aspects usually highlighted.

It was detected that the interests of those who transfer the technology to those who are recipients within an implemented linear transfer scheme are different and have contributed to the construction of the non-functioning of the technology that the interviewees have pointed out. Precisely, an important issue to highlight in the design and technology transfer processes is the lack of genuine participation of users in these developments, whether promoted by the State or private agents. In the cases analysed, they are hardly considered as mere recipients of technology or as labour in self-construction processes. This issue deserves a deeper approach that explores more participatory articulation schemes with end users. For this reason, it is essential to find new development strategies and links between the different agents. In this sense, the technological bias with which the promoters construct the problem to which the CEB technology would provide a solution as the objectives and the linear transfer models that have been applied are not sufficient to adequately consider the existing technological and territorial frameworks for its implementation. This construction system is a topic of interest in current research, however it requires turning its attention from technical aspects to social issues of marketing, production organization and current problems, the perception of technology users and needs of manufacturers, sellers, builders and self-builders. Regarding the attempts to implement the CEB, it should be considered that all technology, when it is transferred from the scenario in which it was designed to the application field, is perceived by new actors in a different way. In this case, it must go through a process of redesign, replication or scaling that generates the instances of adaptation to the new technological frameworks. Conceiving the CEB technological transfer in a broader way will allow us to understand the difficulties of its insertion in other contexts. CEB production processes must be considered anchored in a territory and not only as technical systems meticulously developed within an industry or a laboratory and then taken to the territory to be implemented by users.

Authorship statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the *Hong Kong Journal of Occupational Therapy*.

Please indicate the specific contributions made by each author (list the authors' initials followed by their surnames, e.g., Y.L. Cheung). The name of each author must appear at least once in each of the three categories below.

Category 1, Conception and design of study: P. Dorado, S. Cabrera, G. Rolón, acquisition of data: P. Dorado, S. Cabrera, G. Rolón, analysis and/or interpretation of data: P. Dorado, S. Cabrera, G. Rolón.

Category 2, Drafting the manuscript: P. Dorado, S. Cabrera, G. Rolón, revising the manuscript critically for important intellectual content: P. Dorado, S. Cabrera, G. Rolón.

Category 3, Approval of the version of the manuscript to be published (the names of all authors must be listed): P. Dorado, S. Cabrera, G. Rolón.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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