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INFORMAL SECTOR INCLUSION IN SUSTAINABLE CONCRETE CONSTRUCTION IN AFRICA

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ABSTRACT

Concrete used as a structural material is inevitable in Africa's rapid urban growth, despite its significant contribution to carbon emissions. Hence best practice concrete with reduced Portland cement clinker needs to be applied. The highly informal nature of Africa's construction sector could impede the implementation of sustainable concrete construction. Although urgent need for economisation unintentionally often leads informal actors to operate according to circularity principles, the sector lacks awareness of climate challenges and incentives for adopting climate-friendly materials and technologies. In addition, the informal sector is prone to fraudulent adulterated materials and components causing challenges for safe and durable construction. The authors elaborate on the crucial role of the informal sector in driving sustainable construction forward, despite the lack of policies and disinterest from regulatory bodies. Solutions for education, communication, and quality control are proposed and discussed.

Keywords: *Cement testing, Hydration, Economic development, Informal sector, Cement chemistry.*

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1. INTRODUCTION

The construction industry is responsible for approximately 40% of the global energy demand and carbon emissions [1]. With technology development, the energy demand is expected to decrease in the future, while embodied carbon emissions is anticipated to increase due to the rise in global construction demand, pressing challenges of infrastructure and maintenance in the global North, and an urgent need for infrastructure and urbanisation in the global South. Therefore, responsible use of resources is key for achieving the Paris Climate goals. Moreover, Africa's cities are growing dramatically fast. For example metropolises like Lagos or Kinshasa might have more than 80 million inhabitants in the year 2100 [2]. Other future mega-cities and regions, such as Blantyre or Lilongwe will grow to around 40 million inhabitants from around 1 million today, which opens space for largely unrestricted novel sustainable urban future concepts.

The potentials arising from urban growth are largely on the economic side, whereas the rapid growth also causes enormous pressure on cities with regard to energy demand and materials requirement. Today, the operational phase of a building makes up the largest part of its carbon emissions [9], while the materials demand, the so-called grey emissions, only make up the smaller fraction. Numerous energy-saving technologies have evolved that help to reduce the resource requirements significantly during the operational phase. Since the building stock of sub-Saharan Africa is low, most of the future structures have to be built from scratch [3], making the immediate implementation of emission saving technologies feasible. Therefore, the biggest challenge for African cities is not the operational phase but the inevitable materials demand required for construction. Urbanisation without materials overconsumption can only succeed when principles of circularity are conscientiously applied throughout all supply and value chains.

This particularly applies to concrete, which is the most important urban construction material. It is the only material that is available to meet the global demand, it has a lower carbon footprint than most other structural mass construction materials, and it can be produced nearly everywhere in the world. But due to its sheer global demand, ordinary Portland cement (OPC), the binder of concrete alone is responsible for 8% of the global carbon emissions. Cement and concrete technologies for lower OPC clinker consumption already exist. Yet, in order to create acceptance of sustainable construction materials technologies, all involved stakeholders in the construction process have to appreciate the necessity to build with climate friendly technologies, and tangible incentives have to be provided. At the same time safety of use must be assured.

Today, the approach towards sustainability and circularity in construction is typically based on policy and regulations that assume that a functioning quality infrastructure exists. Incentives for implementing sustainable technologies are typically temporary and driven by policies such as tax releases or subsidies. While governmental incentives are typically exclusively dedicated to the formal sector, in many parts of the world the construction sector is strongly characterised by informality. Existing guidelines, codes, and standards, hence, typically do not reach through to the informal sector and its protagonists. Yet, without capturing all the players in the whole construction chain, the implementation of sustainable construction technologies will not likely going to succeed.

This paper discusses the challenges and potentials that inherently lie within the rapid urbanisation processes in Africa in context with the high level of informality in the African construction sector. While from a policy-maker's perspective the informal sector may be seen as a challenge; from a technical perspective informal practice could be considered as role model for circularity, since typically the informal sector intuitively follows sustainability principles such as reduce, reuse, and recycle for purely economic reasons.

2. AFRICA'S POTENTIALS TO DRIVE GREEN CEMENT AND CONCRETE TECHNOLOGIES

To date, sub-Saharan Africa's contribution to the overall global carbon emissions is marginal in comparison to Europe or the United States of America which have per capita carbon emissions of 8 to 20 times higher, respectively. Even though Northern Africa's emissions are three times higher, the overall per capita emissions of the entire Africa are significantly below the threshold which needs to be reached to achieve the 2050 climate goals [5]. **Figure 1** shows the annual per capita carbon emissions of the countries of the world dependent on the economic power, expressed as annual per capita GDP. The horizontal red line marks the per capita carbon emission threshold that needs to be reached to limit the global warming to 2 °C above preindustrial level [7]. Different colours and the respective linear trendlines indicate different regions in the world. For all plotted regions, a clear trend can be observed that increasing societal wealth correlates with higher per capita carbon emissions. The slope of the curves however differs from region to region. While for the Arab Peninsula countries the general Asian steep trend does not decline significantly, the European carbon emissions increase significantly slower with increasing GDP. The reasons for the lower European trend can possibly be found in policies in place but also in the fact that many carbon-intensive processes related to European production and consumption are sourced out to other parts of the world. The high-income Asian economies and Israel follow a similar trend as Europe. In the lower income regions, the slope is steeper, indicating that carbon emissions are clearly linked to wealth and consumption. For higher income regions, it can be observed that the slope gets less steep, with Macao and Liechtenstein (per capita GDP 141200 USD/carbon emissions of 1.18 tons) lying below the threshold again, showing that high income and special circumstances can invert the upward trend.

Despite these exceptions, it can be seen that all higher GDP countries exhibit significantly higher per capita carbon emissions than the threshold of 2.7 tons. This means, future economic growth in these regions requires minimising wasteful practices and stopping carbon intensive production and consumption. The high carbon emission offset position requires that in these countries, the reduction of carbon emissions must have ultimate priority. In return, a large fraction of the Asian, South American, and African countries lies significantly below the threshold, which means economic growth is not inevitably linked to emission reduction, and societal wealth generation can take place from an already low offset carbon emission level.

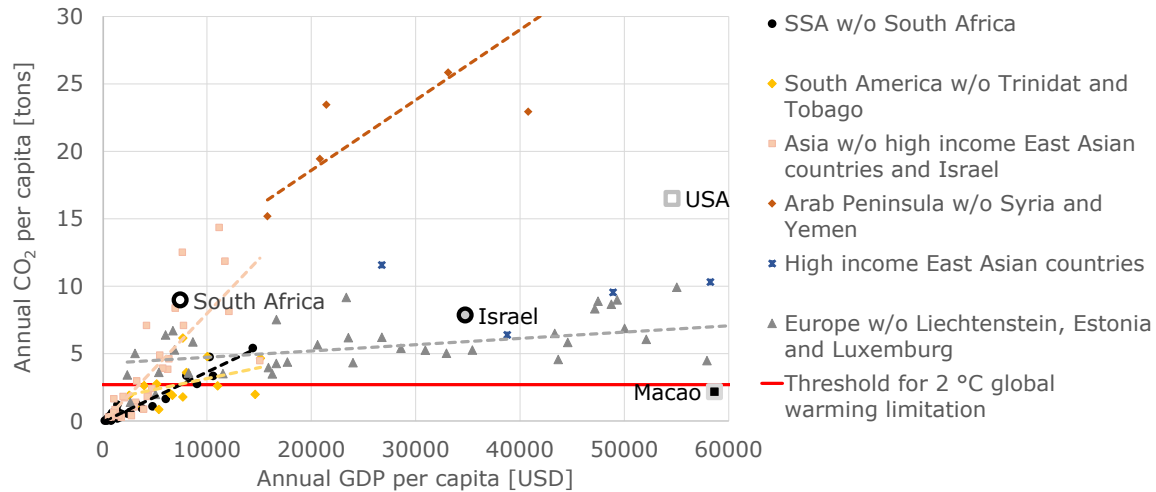


Figure 1. Relationship between gross domestic product and carbon emissions, both per capita, in different regions in the world in comparison to the threshold value that has to be reached in order to achieve the 2°C Paris climate goal (Source of carbon emission data: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States; source of population data: United Nations Population Division, National statistical offices, Eurostat, and United Nations Statistical Division; source of GDP data: World Bank national accounts data, and OECD National Accounts data files).

With the exception of South Africa, which has outstandingly high carbon emissions per capita, over all other countries in SSA the per capita carbon emissions are low. Excluding Seychelles, Equatorial Guinea, Botswana, Mauritius, and Gabon, which are all relatively lowly populated countries, all other countries lie below the threshold line. This gives Africa an incomparable position to shape the economic progress that comes along with the expected industrial and population growth in a greener and more sustainable way than in other regions of the world. The framework to build without extensively high carbon emissions already exists in Africa:

- The continent is rich in clay resources, which provides a tremendous potential for limestone calcined clay cement types [3]. Rapid implementation of low clinker limestone calcined clay cements is even more urgent in Africa, where many regions are dependent on global clinker imports, which inevitably causes cement prices to increase drastically in the near future [4, 5]
- The continent is rich in bio-based resources for conversion to valuable concrete constituents with tremendous growth potentials, since large parts of Africa's arable land areas are not yet used, and the hectare yield is still low in comparison to other regions in the world [6, 7]. Bio-based waste materials often contain polysaccharides that can be useful as performance enhancers such as cassava starch, acacia gum, or *Triumfetta Pendrata* A. Rich [8-11]. Bio-based ashes from agricultural waste, such as rice husks, sugar cane bagasse, cassava peels, coconut shells, cocoa pods, maize cobs, and many others typically provide pozzolanic properties, and thus qualify as SCMs. Unlike all other SCMs, bio-based materials are fully renewable, and thus their use conserves primary resources [11-15].
- Africa has a long tradition of earth based and vernacular materials and technologies. While these are currently often perceived as low-performance, they are typically green and excellently suited, where the structural properties of concrete are not required [16-18].

- Since the African continent provides huge land masses, and many urban structures can be developed right from the scratch, this offers huge potentials to avoid wasteful architectural vision [19, 20]. While building vertically will be inevitably required to tackle the rapid urbanisation challenges, the building height could be limited to the extent at which the additional vertical structural elements to carry the loads becomes unreasonable.
- Urban development can evolve in a more inclusive and socially equitable way. After all, adopting existing urban development concepts will not be capable of coping with future challenges. Materials saving structures, infrastructure and longevity of structural use have to be guaranteed, which includes developing cities that consider all perspectives, as proposed in the FALCONESS 10 Golden Rules [21].
- Existing novel technologies, that are currently well understood and safe to use are often hindered from implementation, since codes and guidelines avoid their application, and changes in standards happen slowly and never disruptively. Africa's level of standardisation is low, and novel standards are required to ensure safe and sustainable application of new materials. However, in developing better regulative frameworks, the currently low level of standardisation turns out to be a degree of freedom to avoid mistakes from the past, to adopt and adapt only existing codes that make sense in the African framework [22], and to develop unique, future-oriented, green construction standards [23].

While the overall framework in Africa is innovation friendly, the fact that 80 % of all urban structures yet to be built until 2050 [24] means there is less than 30 years' time to build better than the rest of the world so far. Hence, implementation of existing green construction technologies has to be facilitated by all players in the field. The rapid implementation requires:

- Applicable standards by all players without unnecessary academisation
- Regulations that address necessary items for safe application but avoid overregulation
- Circularity as a pivotal element in all building codes
- Large scale use of renewable resources prior to using primary resources
- Incentives for application and investments in green technologies
- Willingness to compromise among all players and stakeholders in the built environment.

Already today, the various worldwide stakeholders in construction processes are not aligned, which is one of the significant bottlenecks for the implementation of already existing, greener technologies [25]. On top, in the context of the global South and particularly Africa the high fraction of informal businesses [26, 27] in the construction sector stands out additionally, and thus against a fast, sustainable and safe implementation of novel materials and structures.

3. AFRICA'S INFORMAL SECTOR

The informal sector plays an important role in Africa's construction environment. Global and national policies aim to transform the informal sector to a more formal business. The concept behind is that more tax income can be generated, while in return informal employees can benefit

from governmental support in health and social security. However, in a marginalised, low-income situation, unbureaucratic informality and the accompanying degrees of freedom provide many advantages to its actors, and there is little ambition of the informal sector to change this.

Figure 2 shows the evolution of the informal sector in some countries in Africa where data from different years could be provided by the International Labour Organisation [28]. **Figure 2 a)** shows that the informal business has been increasing rather than decreasing. All countries except for South Africa have a fraction of informal business above 50% with countries like Senegal, Zimbabwe, Mali, or Côte d'Ivoire with nearly 90% or more. A large part of the overall informal business though can be linked to agricultural businesses. In addition, in the non-agricultural businesses shown in **Figure 2 b)**, the median value for Angola is in the order of magnitude of 78.1% with a maximum of 95.6% in Benin Republic, and a minimum of still 15.8% in the Seychelles. It can be observed that in the median and maximum values there is a higher number of women employed in the non-agricultural informal sector. Hence, it can be concluded that the informal sector is a given and dominant reality in SSA, and it is unrealistic to assume that a formalisation can be fast enough to ensure that the ongoing and growing urban African construction will be mostly built by formal and more supervised businesses.

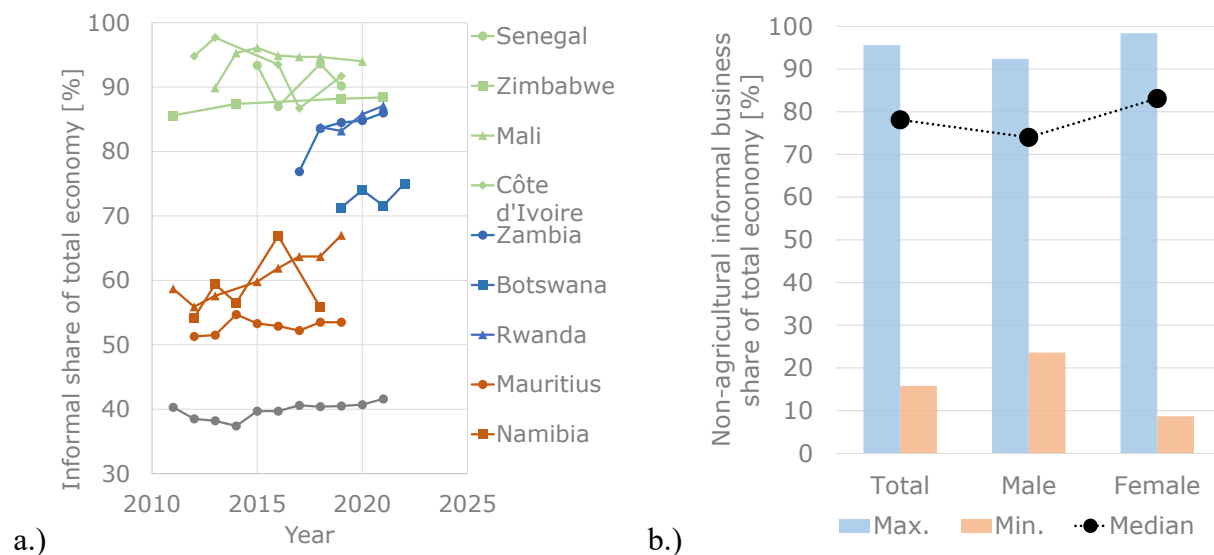


Figure 2.) Development of the informal sector share of the total economy in different African countries (informal sector includes own-account workers, contributing family workers, and employees in informal businesses [28]) (a), and maximum, median and minimum share of non-agricultural informal businesses depending upon gender (b).

Figure 3 shows that from cement production to concrete construction the informal business can be involved on various occasion. SSA is characterised by a strong retail cement bag market, where bags typically contain 50 kg. The fast growth of the industry creates high demand and offers opportunities for untransparent cement sales for international competitors of the local cement producers that abide by local codes. Furthermore, the retail market also makes it difficult to identify if the cement contains what is specified on the bag. For example, it is reported that bags contain less than 50 kg or that parts of the cement are replaced by cheaper powders.

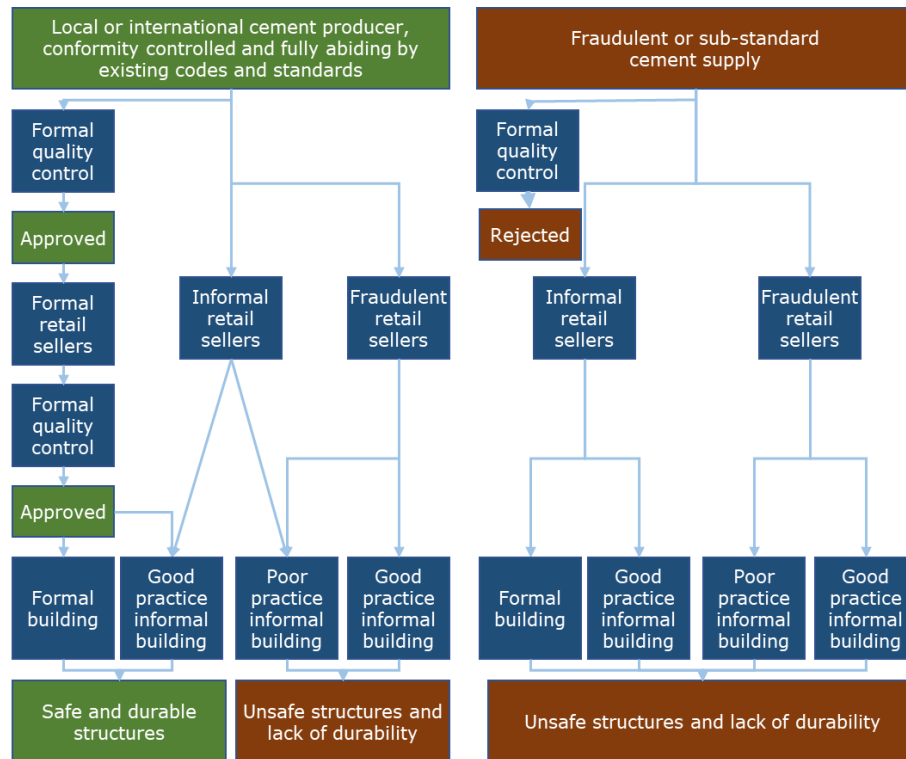


Figure 3. Involvement of the informal sector throughout the supply chain from cement and concrete in the market environment of many sub-Saharan African countries, where the cement market is characterised by international imports and retail markets.

This shows how important a functioning quality infrastructure in the construction market is, and that standardisation bodies play a pivotal role in ensuring safety yet facilitating innovation and low-carbon concrete technologies. Hence without the formal market supervision, construction projects that involve informal businesses are prone to lack safety, durability, and sustainability. This does not mean that the informal sector produces poor quality per-se or acts generally criminally, as often postulated by policy makers. The opposite is true with the informal sector already applying principles of circularity such as reuse, reduce, and recycle naturally, typically due to economic constraints, proving that circularity is also economically feasible. In this context the formal sector could learn from the informal sector. Furthermore, the informal sector is faster to adapt to changes and innovation. However, unlike in the formal sector, the informal sector cannot afford any investment, and hence, for sustainable innovation to be adopted or adapted in the informal business, an immediate tangible economic benefit has to be obvious. In this context, SSA provides a variety of solutions. Bio-based, renewable concrete admixtures, mineral binder components, aggregates and fibres immediately create local livelihoods and potentials to obtain financial gains from unused waste. In addition, circularity potentials and synergies between urban growth and rural development can be created [11, 29].

A major challenge, however, is the lack of continuous formal education in the sector. This often causes challenges with the acceptance of novel and cleaner materials in concrete. It was reported that one significant obstacle for the acceptance of limestone calcined clay cements is that

depending upon the production process the colour can deviate from the classical grey of OPC. Furthermore, on top of the typically limited availability of superplasticisers in the informal business, the knowledge and application awareness are typically not given. Finally, for quality infrastructure institutions, such as standardisation bodies, it is difficult to reach out to the informal sector, firstly because standards are too complex and expensive for informal construction actors, and secondly most institutions lack the financial and personnel capacity to trace all processes in the scattered market. Therefore, the application of novel, greener binder and concrete technologies is limited. Nevertheless, due to the pressing climate challenges and the rapid growth in Africa, measures have to be taken to include the informal sector and facilitate sustainable construction technologies not against but through the informal sector.

4. WAYS TO INTEGRATE AFRICA'S INFORMAL SECTOR IN SUSTAINABLE CONSTRUCTION STRATEGIES

In order to include the informal sector in sustainable developments in the cement and concrete business. It will be required to develop unprecedented concepts, some of which are discussed in the following sections. **Figure 4** shows the role of the informal sector in the application of low clinker concrete. Clinker reduction can be achieved in cement plants directly with the advantage of having a better control of the sulphate content in the binder, or in concrete production with the advantage that smaller and more local supply streams can be utilised [23].

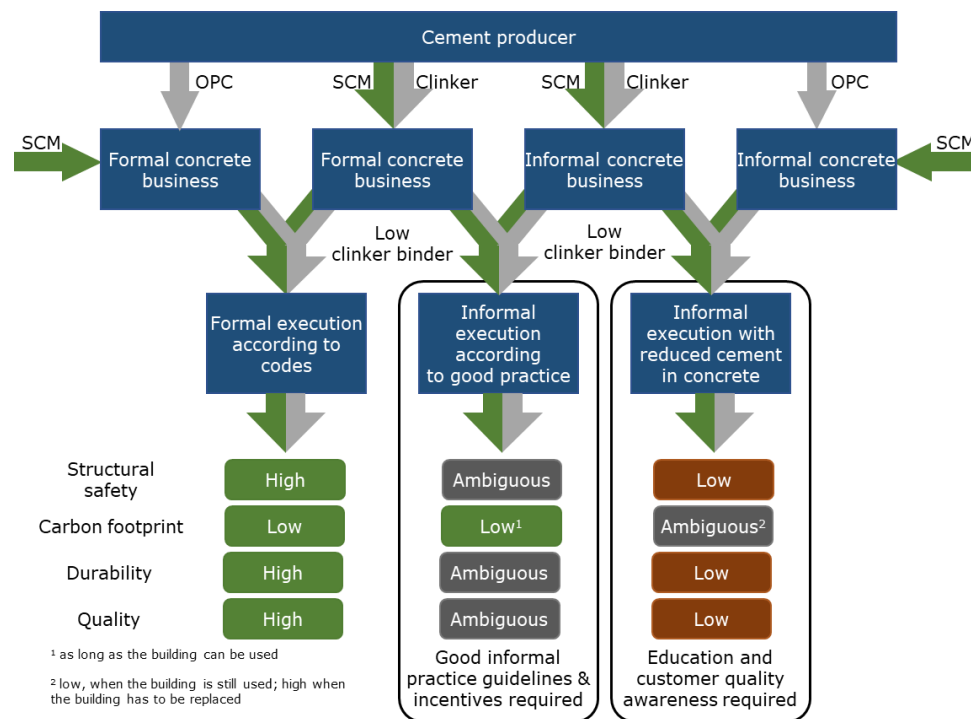


Figure 4. Involvement of the informal sector throughout the supply chain from cement and concrete in the market environment of many sub-Saharan African countries, where the cement market is characterised by international imports and retail markets.

Only an entirely formal execution of the existing standards and codes can ensure that both, safety, and sustainability can be achieved along with durability and high quality. The informal execution does not inevitably have to reduce the quality if the actors are aware of the specific challenges and solutions. However, due to the high number of uncertainties and the lack of control the quality of the materials cannot be assured in the same way as it can be in a well organised, formal framework, where all actors abide by the existing rules. In addition, due to the high prices of cement [23] it is not uncommon practice to minimise the cement in concrete, which among others can be seen as one of the reasons for the multiple structural failures already during the building phase [6]. Therefore, low-clinker binders for concrete are typically perceived as unsafe, as they would aggravate the problems.

4.1. Incentives

The informal sector cannot afford wastage and missing out of income sources can cause severe economic challenges. Therefore, incentives have to be communicated better. Most sustainable materials applications do not require capital investment, rather financial savings can be obtained by using locally available resources instead of products from the international market. In addition, the lower price volatility for locally produced materials has to be communicated as well at the high probability that countries that rely on clinker imports will suffer from tremendous price increases in the future due to carbon taxes and increased fuel prices.

4.2. Provide quality control tools outside the official rules

Due to the lack of market control, the informal sector is prone to become victim of fraudulent practices. Even informal builders with technical skills and knowledge are not save from using sub-standard materials. However, informal players cannot afford quality control according to standards, and they also lack access to formally approved expert knowledge. Therefore, citizen quality control tools with commodity items can become a reasonable and powerful tool to avoid that builders unknowingly use sub-standard materials. Within the framework of an institutional partnership, the Ghana Standards Authority (GSA) and the Federal Institute of Materials Research and Testing (BAM) have started to develop quality control methods with commodity items, which could be brought into the market with support of cement and concrete producers.

Figure 5 shows one such example, where the beverage cola is used along with turmeric powder. Cola typically has a pH value between 2.4 and 3. When mixed with cement (here 0.25 g of cement on 10 g of cola) the cement dissolves with time changing the pH value from below 8 to above 10 over the course of 20 minutes. Turmeric is a pH indicator, that changes from yellowish to red with increasing pH. The conversion takes place at approximately pH 7.4, but a clear change to red can be observed rather around pH 9. **Figure 6** shows an example of the same mixture proportioning over the course of time, and it can be seen that initially the liquid appears yellowish, then changes around 10 minutes before it becomes clearly red after 15 minutes. The colour changes clearly coincide with the changes of the pH shown in **Figure 5**. The figure in addition shows the pH change for a sample where a 20% weight fraction of the reactive clinker was replaced by quartz filler and by quicklime, respectively. The cement with the lower clinker

content remains below the threshold for the colour change, while the immediate reactivity of the quicklime causes the colour change to happen immediately.

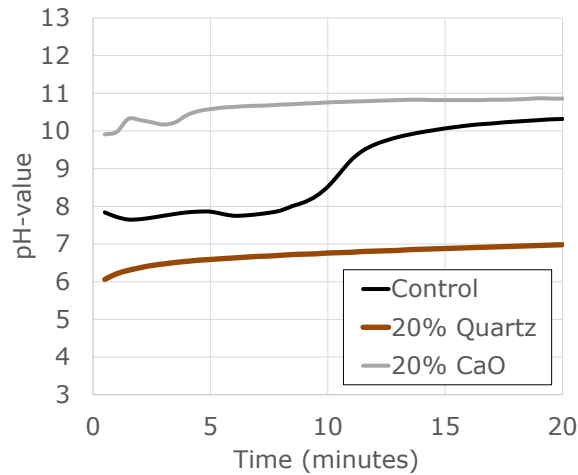


Figure 5. Evolution of the pH value over the course of time for a reference cement, and cements where 20% bwoc are blended with quartz filler or quicklime.

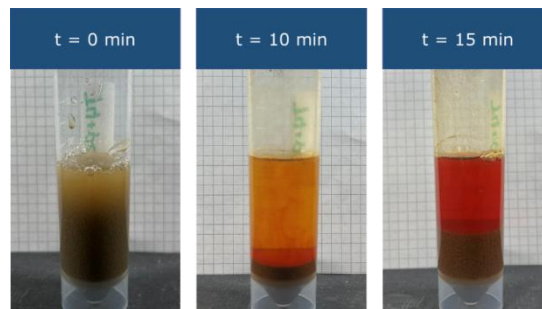


Figure 6. Colour change of the test samples with reference cement over the course of time.

A buyer of cement can easily obtain the required chemical agents as commodity items and hence at least identify if cements that are sold by retailers are suspicious or not. Certainly, further improvement of the test and adoption to blended and low-clinker cements are required. Further quality control tests can comprise fast water demand tests such as the Puntke test [30] or alternatives, sedimentation tests as well as visual tests for wrong bagging or packaging.

4.3. Education

Although self-organised technical educational institutions and associations exist in the informal sector, the majority of actors cannot afford educational courses offered by institutions, timewise and financially. Informal sector actors will thus not actively seek for education in sustainability issues, since for marginalised people, creating an income is the most urgent and top priority. Instead of offering courses to be attended, the lessons have to be transmitted into the sector, and information gain has to be integrated in the daily life of the people. In [31] it was discussed how safe application of materials can be communicated very efficiently with figurative communication, e.g. by arts or on the backside of cement bags. Furthermore, digital media help to get quick and fast access to knowledge. Eventually, awareness of climate change can also be

raised by teaching children, who have a less biased perception, rather than parents about climate issues with the hope that just by daily communication in the families, e.g. through homework with family involvement, climate awareness can be multiplied in a subtle way [32].

4.4. Simplification of standards and building codes to the essence

As also shown in **Figure 3**, there are many intersections between formal and informal sector [33]. This way, existing standards also influence the actions of the informal sector. However, the advantage of being an informal sector player lies in the lack of bureaucracy and surveillance, and the degrees of freedom which come along with it. Therefore, the existing overregulation or movements towards it in the construction sector are not increasing an intrinsic need of informal actors to deal with standards. In general the existing standard systems have grown historically, mostly Euro-centrally, and have reached a level of over-regulation that is rather hindrance to innovative and sustainable construction. In order to motivate informal actors to abide by the standards, systems have to be untangled and simplified. Africa unlike Europe can become a pioneer of green construction technologies and the respective regulations [23]. When standards can be reduced to the essence it is generally easier for all players in the field including the informal sector and the broad public to understand and apply the regulations.

4.5. Translation of standards and codes to tangible language

In addition to the formerly discussed simplification of standards, translations thereof have to be developed in the language or the languages that reach informal actors (**Figure 7**). Pictograms, handbooks, and digital tools can be used to reach the people. Standardisation bodies and industry can work hand in hand to deliver the most urgent messages.

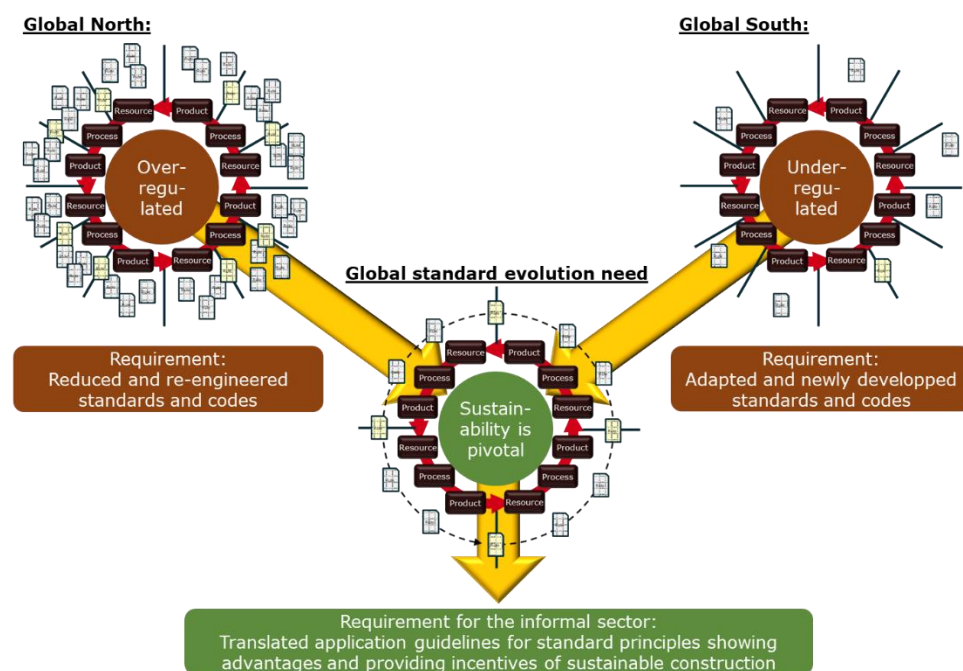


Figure 7. Requirements for standard developments and translation to language of the informal sector.

4.6. Embrace the existing circularity methods

In the general public and authorities, informal business is often perceived as criminal and uneducated. However, in terms of circularity and materials saving the informal sector often applies already for ages, what current policies are trying to establish in the formal economy [34]. Therefore, existing good practice in the informal sector should be incentivised, appreciated, and supported instead of trying to put a formal framework around it, which may have been developed by office workers.

4.7. Create livelihoods through sustainable construction

In the same context, circularity, use of local resources holistically, and the use of materials saving practices in the informal sector needs to be documented and analysed in a macro-economic approach to identify which socio-economic benefits can be created. In return, the positive effects on climate and economy within the informal sector need to be cultivated by governments. Economic gains and livelihood potentials through sustainable construction need to be well communicated to the informal sector to encourage ongoing good practice.

5. CONCLUSIONS

In the light of the climate change, the informal sector points out a challenge for most African economies to implement low-carbon, innovative cement and concrete technologies. The challenges arise since nearly in all economies, the informal business is a significant fraction of the overall economy, whereas climate awareness and low-carbon emissions technologies as well as the respective codes and policies often do not reach the informal actors, who, for good reasons, put different priorities. Since informal economy is a reality in Africa, and it is not realistic to expect informal economies to become formal fast, it is necessary to identify potentials that lie within this sector to drive sustainable technologies fast. This requires different approaches such as creating incentives, citizen quality control methods, education, and simplification of standards along with translation to the needs of the informal economy. In return, lessons can be learnt from good practice, particularly in the field of circularity. This needs to be embraced and developed further. Eventually, low-carbon concrete materials technologies, which use locally available resources are equally climate-friendly and lower-cost, and they create livelihood potentials. Low-cost and livelihoods are among the top priorities of informal players in the construction business. Thus, the enormous power of the informal economy to implement sustainable concrete technologies immediately should be appreciated by policies.

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